THE STATISTICS OF INDUSTRIAL XFEL CAVITIES FABRICATION AT RESEARCH INSTRUMENTS

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Abstract

The serial production of superconducting cavities for the European XFEL was successfully started at RI Research Instruments (RI) at the end of last year. The current status of fabrication is 4 cavities per week. It allows us to summarize the results and present the statistics of industrial cavity fabrication at RI. 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 RI is presented in figure 1. The status of fabrication in August and September not only achieved the necessary level of 4 cavities per week, but also shows the real production capability. RI plans to keep this production rate of at least 16 cavities per month in future.

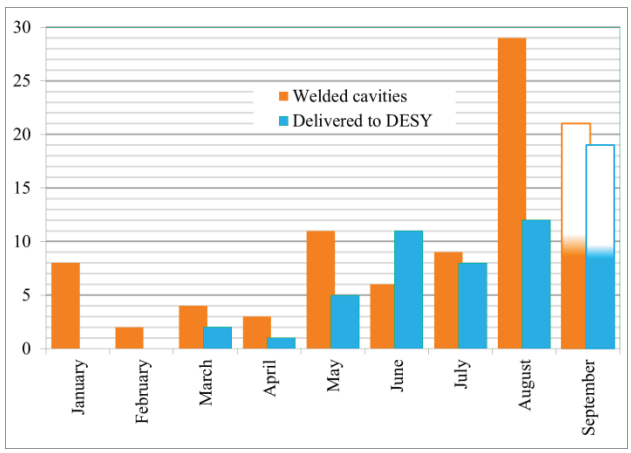

Figure 1: Cavity production rate in 2013 (white area in September shows the cavities in progress).

In the period of 36 calendar weeks since January 2013 RI achieved the following:

- produced 76 cavities up to final electron beam (EB) welding;
- integrated 36 cavities into helium tanks, finished all surface preparation steps and sent them to DESY under vacuum – ready for cold RF test.

It allowed DESY to:

- test 23 cavities under the cold condition;
- send 15 cavities to CEA (Saclay) for module assembly.

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

The results of all measurements done at RI are collected in the XFEL database [3] and were used for this analysis.

MECHANICAL CHARACTERISTICS

The shrinkage of equator welding (see figure 2) depends on the characteristics of the niobium sheets. For the XFEL cavity production the material is delivered from three different suppliers: SE Plansee, Tokyo Denkai and OTIC Ningxia.

The shrinkage parameter is calculated for each of two welded parts: end groups and dumb-bells. So it is a half of the length reduction during welding of one seam.

Before cavity welding the possible different shrinkage of the material from different suppliers has to be taken into account for the calculation of the trimming values for all cavity parts and the estimation of the final length.

The mean shrinkage value for all produced cavities is (0.404 ± 0.010) mm. As can be seen in figure 2, the shrinkage is quite stable and identical for the two material suppliers: Tokyo Denkai and SE Plansee. For OTIC Ningxia material we do not have enough statistics yet.

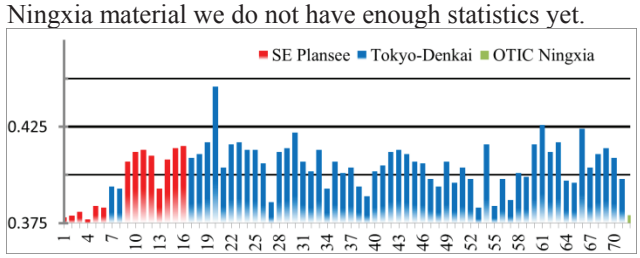

Figure 2: Shrinkage [mm] of equator welding seams for different materials.

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

In order to get stable results in cavity length, the surface removal by electro polishing (EP) has to be done in a controlled way as this will influence the RF frequency and consequently also the cavity length. During the surface treatment of the cavity, a surface removal of 110 µm by EP is done as one of the first steps during the surface preparation. It is necessary that the absolute removal as well as the relative removal between iris and equator does not change during production of the cavities. The same is true for the final EP step, the removal of 40 µm at a later step of the preparation. As the cavity length is quite stable, it proves that the EP process is stable as well at RI.

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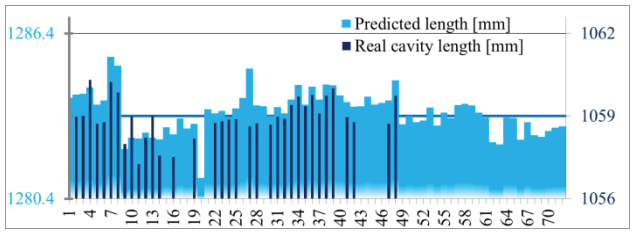

Figure 3: Predicted and real cavity lengths.

The difference between predicted and measured cavity lengths (see figure 3) should be 224.4 mm. It corresponds to: 2 mm length reduction during planned tuning (not taken into account in predictions) and 222.4 mm (lengths of both cavity tubes) due to different measurements (see figure 4: predicted length – between connecting flanges, real – between reference rings).

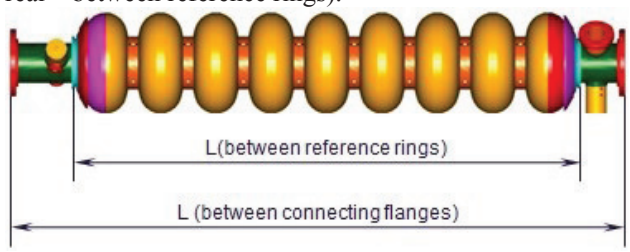

Figure 4: Different methods of cavity length measurements.

The average deviation relative to planned difference is only ± 0.55 mm. This is less than 20 % of the length tolerance.

The average length between reference rings of produced cavities is 1058.96 mm, as required by the XFEL specification (1059.00 ± 3.00) mm.

After 40 cavities produced, DESY requested to reduce the cavity length of by 1 mm. This can be seen for the last 30 cavities.

One can see that the average length reduction is about 1 mm for the last 30 cavities, according to the additional requirements from DESY.

The next important mechanical characteristic for beam dynamics is the cavity cell's eccentricity relative to the cavity axis defined by the reference rings. The maximum of 11 eccentricity values on each cavities (9 for cells and 2 for flanges) are presented in figure 5.

The average maximal eccentricity value for cavities is 0.3 mm. So the cavities are straighter than required by the XFEL specification (0.4 mm).

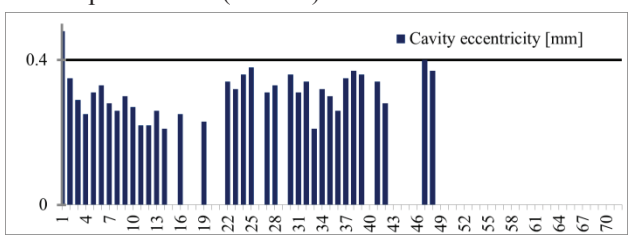

Figure 5: Maximum of cavity eccentricity before welding in helium tank.

RF CHARACTERISTICS

The main RF characteristics for cavity production (TM010 pi-mode frequency and field flatness) are presented in figures 6 and 7.

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

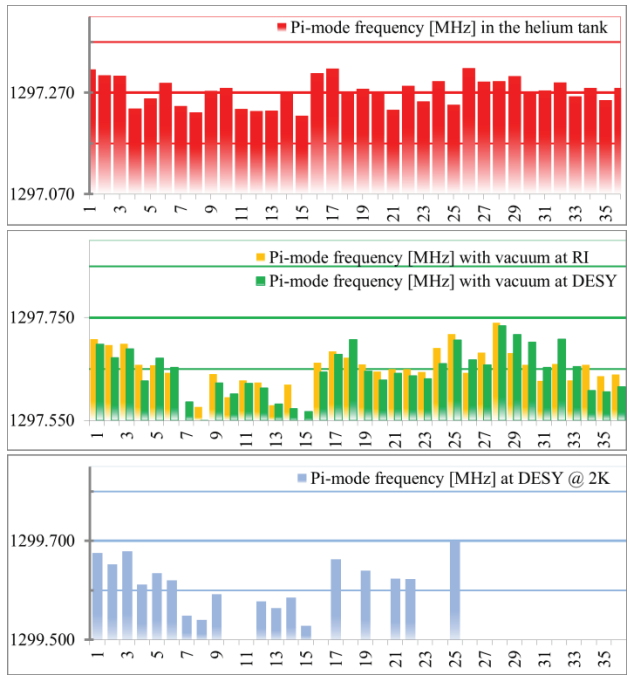

Figure 6: Pi-mode frequencies under different conditions.

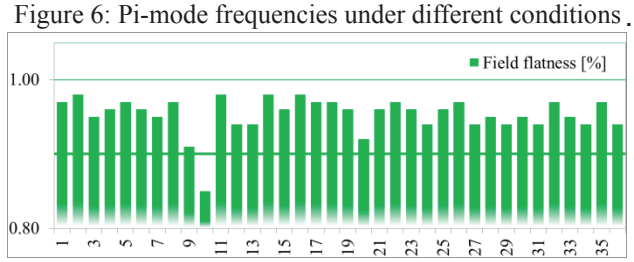

Figure 7: Cavity field flatness at TM010 pi-mode after pressure test.

The average field flatness of cavities, integrated into the helium tank and after a pressure test, is 95 %. It is more than required by XFEL specification (> 90 %). Only one cavity was detuned by the pressure test to below 90 %.

SUMMARY

For 36 calendar weeks in 2013:

- RI Research Instruments (RI) produced 76 cavities;
- 36 cavities were welded into the helium tanks by RI and sent to DESY;
- 23 cavities were tested under cold condition at DESY;
- 15 cavities were sent to CEA (Saclay) for module assembly.

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The main results of the statistics analyzes are:

- welding shrinkage parameter is very stable for the two material suppliers (Tokyo Denkai and SE Plansee). The mean value is (0.404 ± 0.010) mm. For OTIC Ningxia material we do not have enough statistics yet;
- the average length between reference rings of produced cavities is 1058.96 mm, as required by the XFEL specification (1059 mm);
- real cavity lengths are very close to predicted values. So we can define the length reduction to 1 mm according the additional requirements from DESY;
- the average maximal eccentricity value for cavities is 0.3 mm. So the cavities are straighter than it's required by the XFEL specification (0.4 mm);
- after the cold measurement results for pre-series cavities the pi-mode frequency was increased, correcting the target values during the tuning. Further control and correction are planned;
- the average field flatness of produced cavities after a pressure test is 95 % (required more than 90 %).

ACKNOWLEDGMENT

We are thanking all colleagues from RI and DESY, who made it possible to fabricate, prepare, assemble and test the cavities for the European XFEL Project.

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/cavity_production