THPB066

RF Analysis of Equator Welding Stability for the European XFEL Cavities

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Abstract

In order to guaranty a sufficient High Order Modes (HOM) damping in the European XFEL cavities, a detailed analysis of the mechanical cavity production was performed. The mechanical measurements are precise enough to control the shape of cavity parts, but cannot be used for a welded cavity. To estimate the shape deformation during equator welding, the eigenfrequencies of cavity cells are compared with frequencies of cavity parts. This simple RF analysis can indicate irregularity of 9 equator welds and was used in addition to control of mean values for longitudinal and transverse deformations.

Geometry

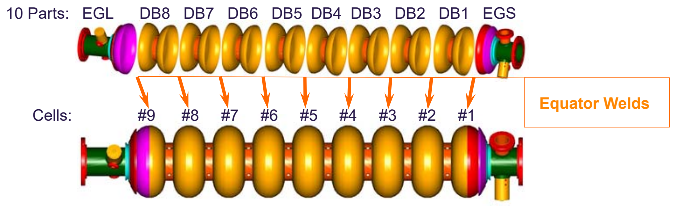

Figure 1: The European XFEL cavity and its parts: dumb-bells (DB) and end groups (EG)

3 factors of frequency changes during equator welding:

1. Joint type (material overlapping - recess);
2. Longitudinal deformation due to melting (shrinkage);
3. Transverse local deformation due to melting.

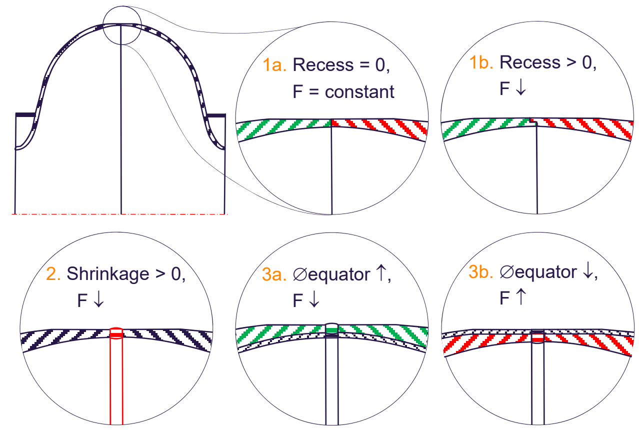

Figure 2: Influence of parts recess (1), welding shrinkage (2) and transverse deformation (3) on cells / cavity frequency

Examples

cavity	δF in cell#, %								
	1	2	3	4	5	6	7	8	9
CAV00029	2	-6	-69	-1	4	3	-14	15	-3
CAV00057	29	-8	5	6	-4	2	1	4	-7
CAV00871	9	-8	-58	-8	-54	2	-10	0	15

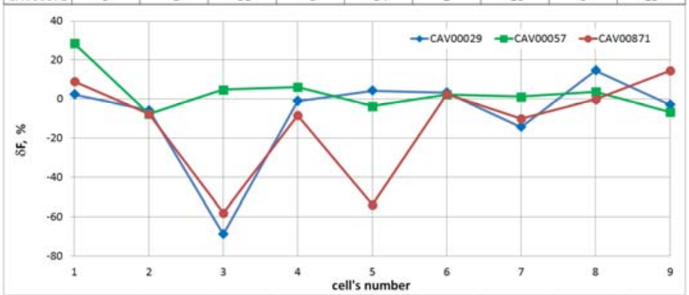

Figure 3: Frequency deviation (2.3) due to deformation during equator welding

Algorithm of Analysis

Calculation of mean values:

Longitudinal deformation due to parts joint and melting (shrinkage):

$$\mathbf{Sh} = \frac{(\sum_{j=1}^{10} L_j - L_a)}{18} - R, \qquad (1.1)$$

where: $\mathbf{Sh}$ – mean shrinkage per each piece of a weld;

L_j – length of a cavity part (j = 1 – L_{EGS}, 2…9 – $L_{\mathrm{DB\#}(j\text{-}1)}$, 10 – L_{EGL});

L_a – length of a cavity after welding;

R – planned recess per each piece of a weld (if it is not zero).

Transverse local deformation due to melting:

$$\mathbf{Def} = F_a - \frac{\sum_{j=1}^{10} F_j}{18} - Fl, \qquad (1.2)$$

where: $\mathbf{Def}$ – frequency changes per each piece of a weld;

F_j – frequency of a cavity part (j = 1 – F_{EGS}, 2…9 – $2F_{\mathrm{DB\#}(j\text{-}1)}$, 10 – F_{EGL});

F_a – pi-mode frequency of a cavity after welding;

F_l – correction due to longitudinal deformation.

Deformations in different cells:

Frequency changes in cell #(i), i = 1…9 can be described as:

$$\Delta F(i) = \frac{Fp(i) + Fp(i+1)}{2} - Fc(i), \qquad (2.1)$$

where: $Fc(i)$– eigenfrequency of a cell, which can be found, based on RF measurements (spectra and field amplitudes) after cavity welding [1];

$Fp(j)$ – frequency of a cavity part (j = 1 – F_{EGS}, 2…9 – $F_{\mathrm{DB\#}(j\text{-}1)}$, 10 – F_{EGL}).

Average frequency changes (2.2) shows mean deformations in all cells:

$$< \Delta F >= \frac{1}{9}\sum_{i=1}^{9}[\Delta F(i) \cdot C(i)], \qquad (2.2)$$

where: $\Delta F(i)$ – frequency deviation (2.1);

$C(i)$ = 1 – weight factor.

Regularity of cavity equator welds (i = 1…9) can be described by the frequency deviation relative average value:

$$\delta F(i) = \frac{\Delta F(i) - <\Delta F>}{|<\Delta F>|} 100\%, \qquad (2.3)$$

For irregular welds, if deviation (2.3) is more than 20%, weight factors for these cells have to be changed to $C(i)$ = 0 and parameters (2.2…2.3) calculated again.

Summary

- Mean values calculation (1.1) and (1.2) for cavity equator welding is performed for the European XFEL. It allows us control of the behavior of the Electron Welding Machines for different material suppliers during series cavity mass production. Statistics for two types of deformations (longitudinal and transverse) are used for cavities' sub-components preparation (trimming).
- Transverse deformation are usually caused by the forces, which join two welding parts together, and gravity. It also depends on cavity and electron beam orientation during welding:
  - vertical cavity orientation usually causes increase of equator diameter and frequency reduction (Def < 0);
  - horizontal orientation decreases equator diameter and increases cavity frequency (Def > 0), if electron beam comes from the top. Otherwise it is identical to vertical cavity orientation.
- Analysis of welding irregularities in different cells of a cavity was developed after beginning of the European XFEL cavities production and was not included in standard procedure.
- Uncertainty of irregularity determination is caused by the possibility of frequency deviation compensation by different types of deformation (longitudinal and transverse).

References:

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