

POST-PRODUCTION DIMENSIONAL CONTROL OF THE COLD MASSES AND VACUUM VESSELS FOR THE XFEL CRYOMODULES

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Abstract

The very tight alignment tolerances of 0.5mm required in the XFEL Linac reflect in very tight tolerances for the production of the main cryomodule components. To verify the adherence to the specified tolerances of the cold masses and vacuum vessels, dimensional controls with laser tracker are performed at the production site following DESY experts' instructions and are verified at DESY with an independent measurement. We present here the measurement strategy and a summary of the results obtained so far.

INTRODUCTION

Two of the main components, the Vacuum Vessel (VV) and the Cold Mass (CM) (Figure 1), of the one hundred and three cryomodules that will form the XFEL linear accelerator [1] are now under series-production at two different facilities: E. Zanon company in Schio, Italy and CX company in Wuxi, China.



Figure 1: A XFEL cold mass at the production site.

The quality of these components is a key factor for the quality of the whole accelerator and is constantly monitored during the whole production cycle. More details about all the activities related to the quality control of CMs and VVs can be found in [2].

Among the QC activities, the dimensional control of the main sub-assemblies is a fundamental part of the component acceptance tests. The cryomodule is essential for the cavity string alignment: the cavity support system has to guarantee an alignment of the cavity string with a

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precision better than 0.5 mm. Therefore, dimensional controls with laser tracker of the pre-assembled cold masses and the vacuum vessels are performed at the construction sites after the final machining and, additionally, at DESY or CEA-Saclay as integral part of the incoming inspection.

LASER TRACKER

Laser trackers are available from a wide range of manufacturers with similar measurement accuracy. Laser trackers measure 3D-polar coordinates; typical accuracy levels are 2.5 μm for the horizontal and vertical angle and 10 μm for the distance measurement [3]. The position accuracy of a measured coordinate is therefore dependant on the distance. A maximum measured distance of 8 m corresponds to a maximum error of 20 μm , caused by the angular measurement. With this accuracy value we are a factor of 10 below the minimum position tolerance of 0.2 mm (200 μm).

MEASUREMENT PROCEDURE

Measurement Procedure as Defined by DESY

The measurement has to be performed in a temperature controlled area, with stable floor, stable instrument and object stands; only qualified and trained personnel should perform the measurement with calibrated instruments.

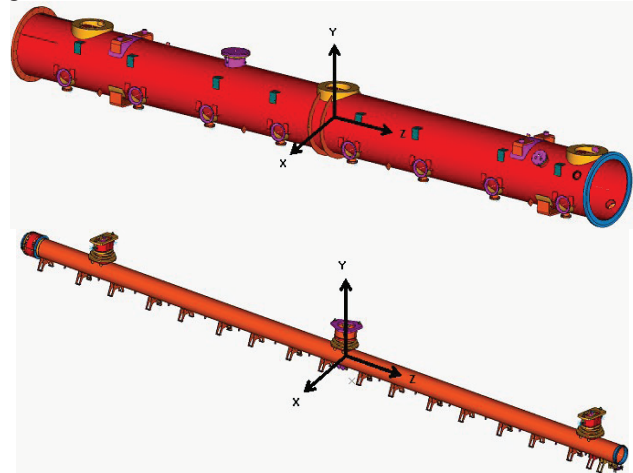


Figure 2: Coordinate system for VV (up), and CM (down).

During the measurement the VV should be placed horizontally on its feet while the CM should hang from the three support posts. While the VV can be considered as a rigid body, the CM is much more pliable and has to be suspended stress-free during the measurement. The posts of the CM have therefore to be mounted on horizontal roller bearings and vertically adjusted before performing the geometric control.

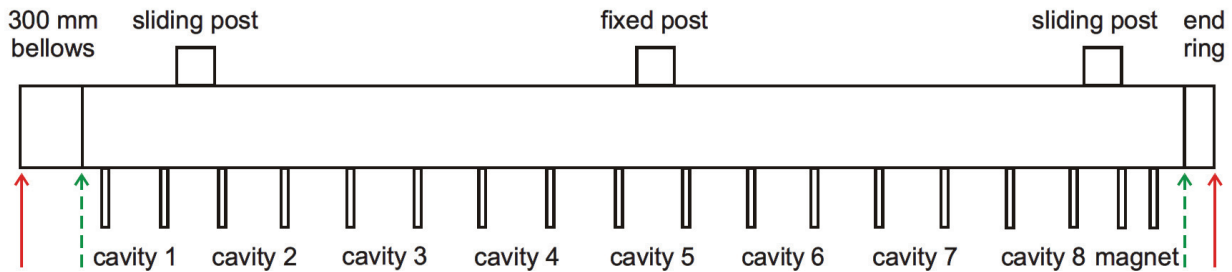


Figure 3: Axis references, **Red full**: reference in DESY, **Green dashed**: initial reference in Zanon and CX.

The reference axes of the VV are the axis connecting the centre of the two end flanges, the vertical axis through the central post and the axis perpendicular to both (Figure 2). Besides the obvious dimensions, like length and diameter of the VV, the positions and orientations of post and coupler openings are especially important here.

The reference axes of the CM are the axis connecting the centre of the two end flanges of the helium return pipe, the axis through and normal to the central post and the axis perpendicular to both (Figure 2).

For the CM the tolerances of the “shapes” (the cavity support system) are extremely tight (0.3mm laterally and 0.5mm in height over the whole length of approximately 12m) and thus controlled extensively by the measurements.

Measurement Procedure at the Companies

The measurement of the CM done at Zanon and CX at the beginning of the production was slightly different than the one required by DESY: at CX the first pipes were machined before the final welding of the ring and bellows and therefore the ends of the “naked” pipe were used as reference for the machining and the coordinate system (Figure 3). This of course led to an inaccurate definition of the coordinate system and consequently to faulty results of the measurements, causing rejections of CMs during the incoming check at DESY.

At Zanon the machining was done after the welding, but the reference was anyway based on the end of the “naked” pipe, since the company didn’t want to rely on the bellows transport sleeve for such a delicate operation (the bellows are pre-compressed to protect them during production). This led to similar results as from CX.

After the first dimensional controls were repeated in DESY using the end of the ring and bellows as a reference, it was clear that the two measurement methods were not compatible. The companies therefore changed their production and measurement scheme and agreed to use the same reference as DESY for the machining and measurement of the cold masses.

Measured Quantities in the VV

Once the VV is correctly positioned and the reference axes determined, these quantities are measured:

- the X, Y, Z position and orientation of the 3 post openings; tolerance values: $T_x = T_y = \pm 1.0$ mm, $T_z = \pm 3.0$ mm, parallelism to xz-plane = 0.3 mm, planarity = 0.2 mm.

- the X, Y, Z position and orientation and the 8 coupler openings; tolerance values: $T_x = T_z = \pm 1.0$ mm, $T_y = \pm 0.5$ mm, parallelism to yz-plane = 0.5 mm, planarity = 0.3 mm.

Measured Quantities in the CM

Once the CM is correctly positioned and the reference axes determined, these quantities are measured:

- the X, Y, Z position and orientation of the 3 posts; tolerance values: $T_x = T_y = \pm 0.5$ mm, $T_z = \pm 3.0$ mm, $T_{rx} = T_{rz} = \pm 0.2$ mrad.
- the X, Y, Z position and orientation and the cavity and quadrupole brackets; tolerance values: $T_x = \pm 0.3$ mm, $T_y = \pm 0.5$ mm, $T_z = \pm 1.0$ mm, parallelism to xz-plane = 1.0mm.

If all measured values are within tolerance during the check at the manufacturer’s site, the CM or VV is preliminarily accepted and permission is granted to ship the structure to DESY or to CEA.

If all measured values are within tolerance during the incoming inspection at DESY or at CEA, the VV or CM is automatically accepted and stored for later use. If certain tolerances are exceeded, an individual evaluation is made together with the manufacturer.

RESULTS

The vacuum vessel is a much more rigid structure than the cold mass and its production is therefore less critical: all the vessels measured so far at the two production sites are overall within the DESY specifications. As an example, Figure 4 shows the measurement of the coupler port vertical position for the first 10 vacuum vessels produced at Zanon. It can easily be seen that all measured values stay in the tolerance of ± 0.5 mm.

The cold mass, on the other hand, is a flexible and easy deformable structure, sensitive to mishandling during production and transportation. In some cases the dimensional controls have highlighted problems of deformation either during the handling at the company or during transportation.

A “Bad” Example: IHEP-CX005

Figure 5 shows the lateral alignment of the IHEP-CX005 cold mass. The measurement has been performed at CX and repeated 2 times at DESY using the “naked” pipe or the end ring and bellows as reference.

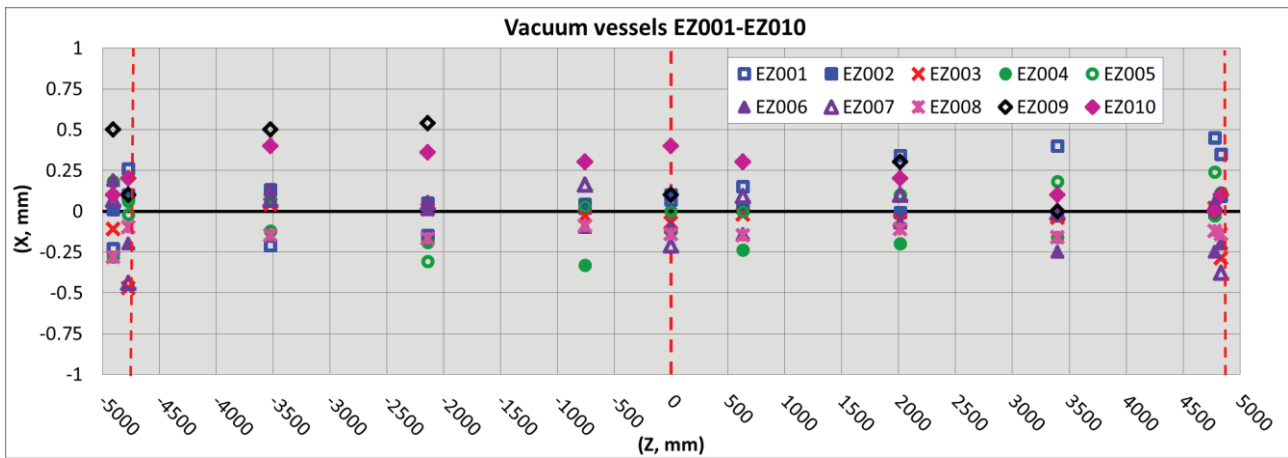


Figure 4: Axis references, **Red full**: reference in DESY, **Green dashed**: initial reference in Zanon and CX

The picture clearly shows that the CM got highly deformed after the measurement in China: the pipe had a “banana-shape” after the arrival at DESY, with a maximum deformation of about 3 mm, while the tolerance value is just 0.3 mm. It is suspected that the shown deformation was caused by careless crane operation at the manufacturer’s workshop. This CM was rejected by DESY and sent back for repair.

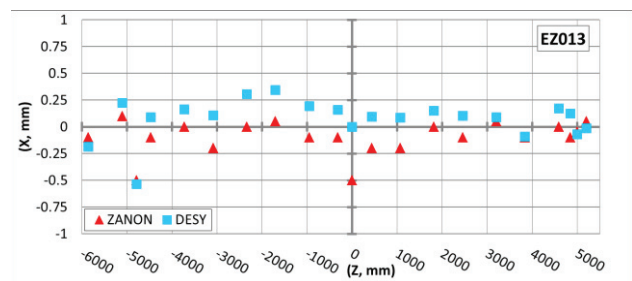


Figure 7: Lateral alignment of the Zanon EZ013 CM.

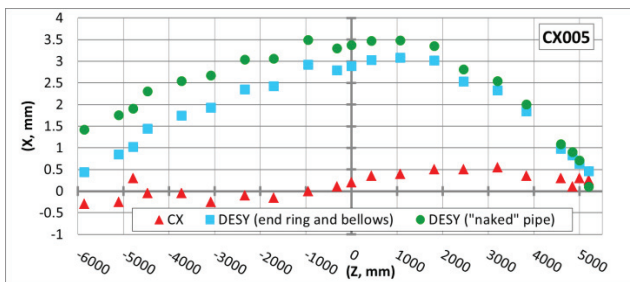


Figure 5: Lateral alignment of the IHEP-CX005 CM.

Two good examples: IHEP-CX009 and EZ013

Figure 6 and 7 show two good examples, one from CX and one from Zanon, where the estimated values from the manufacturer are in tolerance and in good agreement with the ones measured at DESY at reception.

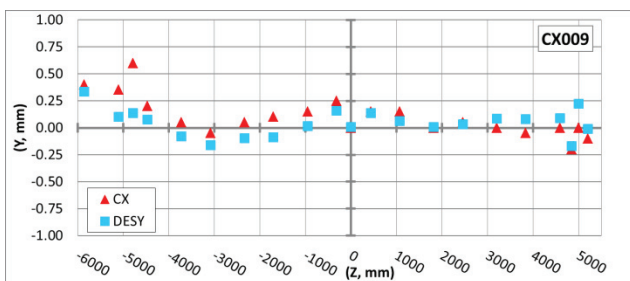


Figure 6: Vertical alignment of the IHEP-CX009 CM.

These examples show that the manufacturing and transportation of a fragile structure like the CM is feasible within the required tolerances.

CONCLUSIONS

More than 30 sets of cold masses and vacuum vessels have been produced so far at the two production sites. Most of them have already undergone the incoming dimensional control at DESY or CEA-Saclay and have been accepted for the final cryomodule assembly.

At the beginning of the production, the dimensional control of the components has highlighted some mistakes in the fabrication process and handling of the cold masses. These problems have been addressed by the companies together with experts from DESY. The latest results show a better quality and now normally satisfy the DESY requirements, making the dimensional control a fundamental part of the quality control process.

ACKNOWLEDGMENT

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