

MECHANICAL FABRICATION OF ESS-BILBAO RFQ

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Abstract

The fabrication of the first segment of ESS-Bilbao RFQ started in 2016. The segment, of about 800 mm in length, is an assembly of 4 elements: two major vanes and two minor ones. The assembly of the cavity will be done by using polymeric vacuum gaskets instead of welding or brazing the elements. Apart from conventional CAD systems, a custom home-made tool for vanes geometry has been successfully used. Machining process from copper blocks to final elements is described in detail. To test and validate the chosen vacuum strategy, an aluminium model using the same gaskets as the final cavity was built and tested. The complete first segment was expected to be fabricated early 2017, but due to some difficulties hereby explained, vacuum tests are delayed to second half of 2017.

INTRODUCTION

ESS-Bilbao is designated to supply Spanish in-kind contribution to European Spallation Source ERIC (ESS). There are contributions in the accelerator (MEBT), the target and in the instruments. In addition to the in-kind contribution activities, local projects are also under development, with the main goal of testing components to ESS project and become the first stages of a future local accelerator. A proton injector is being set up, consisting on an ECR ion source and a LEPT [1] already in operation, followed by an RFQ linac presented in this communication.

The ESS-Bilbao RFQ design (see [2,3] and references therein) was carried out by a local team taking the designs for ISIS-FETS and Linac4 RFQs as references. After a review by a panel of experts in 2013, the RFQ underwent a major revision that resulted in the present design. A Technical Design Report with all the design process and modifications can be found in [3].

The RFQ is a 4-vane structure. It has a total length of about 3.1 meters, divided in 4 segments of about 800 mm length each (Fig. 1). The segment length is determined by the machining equipment available for fabrication of the vanes. Segments are an assembly of 2 major and 2 minor vanes, assembled together by using polymeric vacuum gaskets instead of brazing or other welding system. Material is copper OHFC (Cu 10100) quality.

The fabrication of the first segment was awarded by public tender to the company AVS [4]. The RFQ is

currently under fabrication, and first tests are expected to start during 2017.

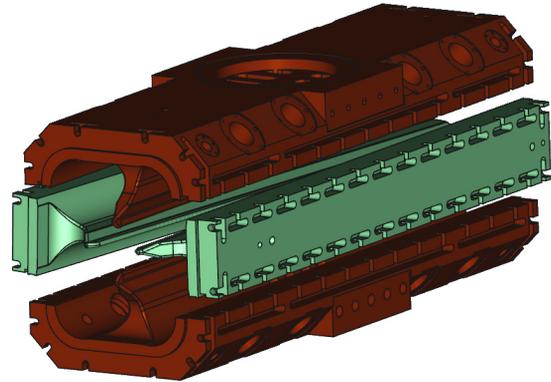


Figure 1: Exploded view of first segment of the RFQ, separated in two major and two minor vanes.

MECHANICAL MODEL

Starting from the electromagnetic design of the RFQ cavity a CAD model of the structure was built. The ports for tuners, vacuum grid and all other mechanical features were implemented in the model. RF and thermo-mechanical simulations were then ran again to validate the design.

The vane modulation was obtained from beam dynamic codes and analysed using COMSOL and other software. The curve defining the modulation is defined in geometry construction by means of an interpolation of individual points. The transverse cross-section of the vane tip (semi-circular) is then extruded along the line of the modulation. The constructed geometry was then inspected to validate the geometry constructed: the curve corresponding to the modulation was extracted from the solids by different methods (directly from the STEP file format or after importing in COMSOL). We were not satisfied with the results obtained when comparing the extracted curves to the theoretical ones. We detected that discrepancies were caused by the construction of the initial curve done by the CAD software: the interpolation of the big amount of 3D points (up to 200 per modulation cell) was not done correctly by the CAD tools we had available, resulting in a modulation curve with strong deviations to the design one.

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A custom home-made code was then built, making use of OpenCascade kernel, to avoid this problem and build the modulation solids with great accuracy and control. This software can also create models of the RFQ vanes that were easy to incorporate in FEM simulation procedures.

FABRICATION STEPS

Raw Material

The material for the fabrication of the RFQ was supplied in blocks of two different sizes: 270x140 mm for major vanes and 115x140 mm for the minor ones. Length of all blocks is 830 mm. The copper grade selected is Cu OFE C10100.

Squaring and Deep Drilling

The first step in the fabrication process is to evenly square the copper blocks, to assure that each face is parallel to the opposing one and perpendicular to the others. Marks to fix the position of the cooling channels are machined in the corresponding faces (Fig. 2).



Figure 2: Squared block for a major vane fabrication. Holes to guide the deep drilling of the cooling channels are also shown.

The deep drilling of the longitudinal cooling channels is then done. This is made during the first steps of the fabrication process. Channels will then serve as reference for the rest of the geometry. In this way, the effects of a possible deformation due to the machining is minimized as major machining is done afterwards. A model showing the channels is shown in Fig. 3.

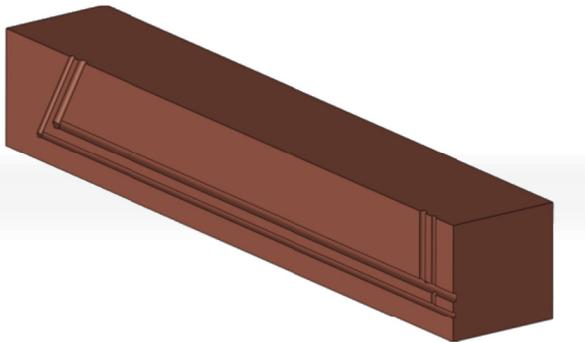


Figure 3: Model showing the deep drilling of the longitudinal cooling channels.

At this stage, the two channels are connected and open in the back side (higher energy) of the RFQ segment. They will be sealed in a later step.

Rough Machining and Stress Relief

The rough machining of the vane is then done. An excess of about 3 mm from the final shape is left in all dimensions. A stress relief (200 °C during several hours) heat treatment is also performed. Fig. 4 shows details after this stage.

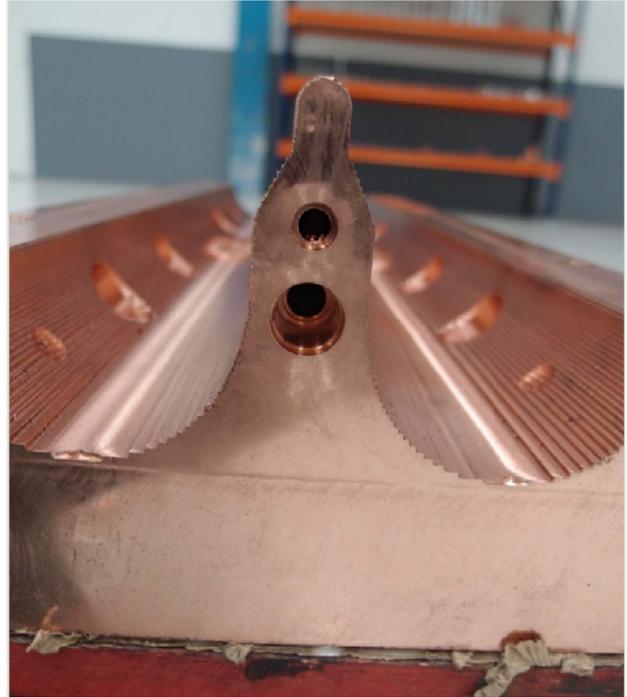


Figure 4: A major vane after rough machining. The holes of the cooling channels can be seen in the vane.

EBW of the Cooling Channels Plugs

Cooling channels are then sealed by inserting copper plugs and welding them. This is carried out by our staff at ESS-Bilbao's Advanced Welding Facility by means of electron beam welding (EBW). Three plugs are inserted and welded, one to separate the two channels and the other two to seal them from the external face (Fig. 5) In the final steps of the process this face will be machined, and no external evidence of the welding of the plugs will be visible.

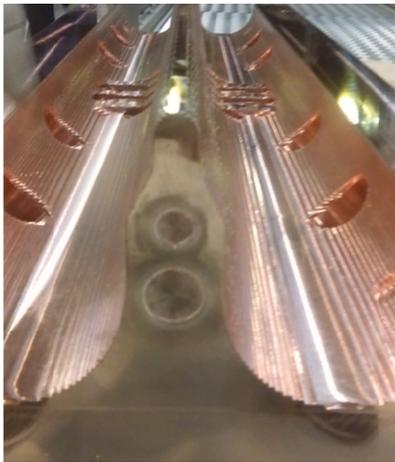


Figure 5: A major vane after cooling channels plugs have been inserted and welded by EBW.

Fine Machining

The last fabrication step for a vane is the fine machining, where all the final details are included. Particularly, the vane modulation needs a careful process in a temperature controlled machine to avoid over-heating that could give rise to deformations. Fig. 6 shows a major vane in the milling machine.

The milling of the modulation is made using a CAM controlled, 3-axes, HERMLE C800V machining centre. Many displacements of the tool on the copper surface are used, removing a very thin layer each step. This increases milling time but also provide excellent surface quality (roughness 0.8 R_a and mechanical tolerances around 0.005 mm.

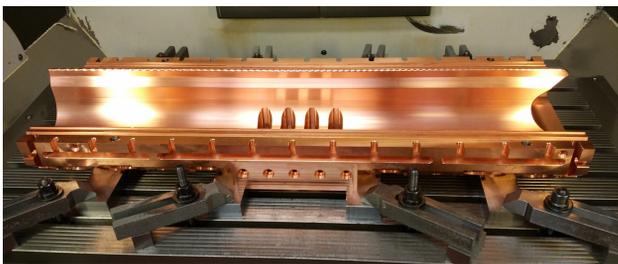


Figure 6: A major vane of the RFQ after fine machining in the milling machine.

Metrology

The final step is the metrology of the fabricated piece. Special care is taken in the measurement of the vane modulation profile. After control of the first major vane, a deviation of the modulation measured with respect to the design one was detected, despite the attention paid to the machining process. To correct this, a second machining of the modulation profile was performed (Fig. 7), lowering the height from the bottom face by 100 μm . The contact faces between major vanes and the two minor vanes were also machined removing the same height of material, so

the four vane tips have the correct distribution after assembly.

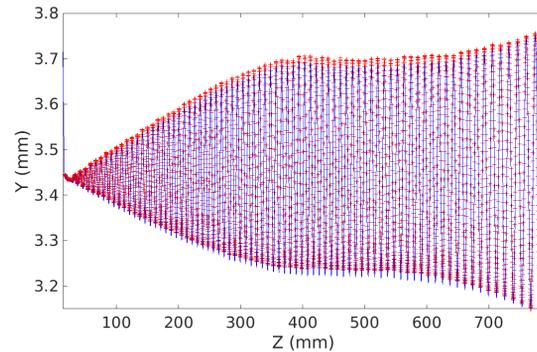


Figure 7: Comparison of measured modulation to theoretical one.

Apart from this issue, the metrology results of the first vane of the first segment (only one was finished while preparation of this contribution) is very satisfactory.

VACUUM STRATEGY

The vacuum strategy for the cavity is based on the use of polymeric vacuum gaskets at the unions between major-minor vanes, and also on the contact faces between the assembly of four vanes and the cover or inter-segment ring. Once the four vanes are assembled (as in Fig. 1) and the alignment verified, the groove for the O-ring in the front side will be machined.

This approach will allow assembling or disassembling the RFQ in case of misalignment or other problems. This strategy will be thoroughly tested with the first segment, in terms of vacuum levels and other issues. If results are satisfactory, the same procedure will be used for the rest of the segments. If results are negative, the strategy will be revisited and brazing of vanes will be considered.

These results were planned to be presented in this contribution, but due to the several months delay on the fabrication, tests have not yet been started.

CONCLUSION

Fabrication of the first segment of the RFQ is ongoing. Although planned to be finished for 2016, up to now and due to delays only one of all four vanes (two major plus two minor) was finished. The whole segment is expected to be received for the third quarter of 2017. Vacuum and RF tests will then get started.

REFERENCES

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