MECHANICAL DESIGN, BRAZING AND ASSEMBLY PROCEDURES OF THE LINAC4 RFQ

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Abstract

The Linac4 RFQ will accelerate the H^- beam from the ion source to the energy of 3 MeV. The RFQ is composed of three sections of one meter each, assembled by means of ultra high vacuum flanges and adjustable centring rings. The complete 3-m long RFQ will be supported isostatically over 3 points like a simple beam in order to minimise the maximum deflection. The ridge line, used to feed the RF power into the RFQ, will be supported via springs and its position adjusted in such way that no strain is introduced into the RFQ at the moment of its connection. The mechanical design has been done at CERN where the modules are completely manufactured, heat treated and brazed also. In that way, all of the processes are carefully controlled and the influence, notably of the heat treatments, has been understood in a better way. Since 2002 several four vanes RFQ modules have been brazed at CERN for the TRASCO and IPHI projects. A two-step brazing procedure has been tested. This technique is actually used for the assembly of the CERN Linac4 RFQ. This paper describes the design, the mechanical procedures adopted for machining and assembly and the first results obtained.

INTRODUCTION

CERN has started the construction of a Radiofrequency Quadrupole (RFQ) Accelerator designed for the Linac 4. The RF and accelerating parameters have been already described [1]. The construction consists of three modules, brazed-copper, four vanes, each one meter long and directly coupled.

In a previous paper, we have presented the two-steps brazing procedure developed at CERN in collaboration with the TRASCO (INFN) and IPHI (CEA) projects [2]. The four vanes, two major and two minor vanes, are first brazed in horizontal position into a horizontal vacuum furnace. In the second step, the module is re-machined and the lateral and end flanges are brazed on the module in a vertical vacuum furnace.

Our observations with the TRASCO and IPHI projects have shown that the main difficulties come from the constraints produced during machining and allowing relaxation movements during the first brazing step.

In the case of the Linac 4 RFQ, we have tried to simplify the machining and to add the necessary heat treatments to reduce the constraints inside the copper vanes before the first brazing step. This paper describes the mechanical procedure developed and tested on a dedicated major vane. The results obtained after the first brazing of the first module are also presented.

MECHANICAL DESIGN

The Linac 4 RFQ design has taken advantages from the RF design experience of the IPHI RFQ. For this reason the two RFQ's have some similarities.

The Linac 4 RFQ design has introduced some important characteristic for the cavity shape (Fig. 1): corners are present on both sides of the horizontal brazing surfaces in order to reduce the possible flow of the brazing alloy toward the vane tips. The 2D section is constant over the full length in order to simplify the machining. The vane modulations are machined using a wheel shaped cutting tool. The pumping ports are brazed onto the module in order to avoid the machining of the grids directly into the major vanes.

Efforts have been also made to simplify the support. The three-meters long RFQ will be simply supported isostatically over three points like a beam. The ridged line, connecting the klystron output to the RFQ cavity, will be supported with springs in such a way that no strain is introduced into the RFQ.

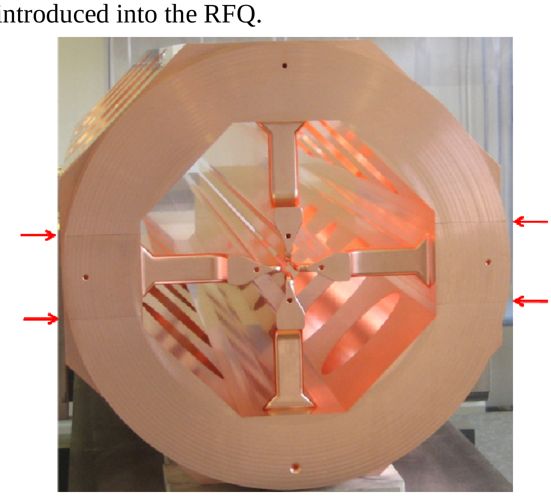

Figure 1: Front view of the first Linac 4 RFQ module. The arrows point the brazing surfaces.

MANUFACTURING PROCEDURE

The manufacturing procedure, up to the first brazing step, is the following: rough machining with 1 mm over thickness, first heat treatment, partial finishing with 0.15 mm over thickness only for the vane tips and the brazing surfaces, second heat treatment and finishing.

A major test vane has been machined to test the procedure. In this case the two heat treatments have been limited at 600 ºC in order to reduce the grain growth.

After the second treatment, the machining of each vane is expressly limited to narrow surfaces: the vane modulation and the brazing surfaces. This way, we expect to limit the mechanical constraints introduced by machining before the first brazing cycle.

This procedure has been applied for the machining of the test vane. A heat treatment at 800 ºC has been used to simulate the first brazing step.

Our measurements of the planarity of the brazing surfaces after this treatment have been quite unsatisfactory. Starting with a planarity of 28 µm, we have measured a planarity of 65 µm after treatment corresponding to a deformation of the brazing surfaces of about 40 µm. This is less than observed in the same conditions with an IPHI major vane (~ 100 µm) [2], but more than expected.

At this stage, it was not possible to decide if the constraints have been introduced during the finishing step or the relaxation during the second treatment at 600 ºC wasn't efficient. We have then submitted this test vane to an additional heat treatment at 800 ºC. This time the planarity didn't change and the deformations were less than 20 µm showing that a treatment at 800 ºC is efficient for a complete relaxation of the constraints.

Afterward, a new finishing step has been performed on this test vane followed by a heat treatment at 800 ºC simulating a new brazing step. Little deformations, less than 10 µm, of the brazing surfaces have been measured. This has confirmed that our final machining is not a source of constraints. It was then decided to keep the original manufacturing procedure for the RFQ modules with a change of the temperature of the second heat treatment performed at 800 ºC instead of 600 ºC.

ALIGNMENT PROCEDURE

The finishing of the major vanes is made first and then the modulation profiles are measured. The results are used to optimise the thickness of the minor vanes which are finished afterwards.

The positions of the reference holes used for alignment for each vane are determined by minimizing the error measured on the modulation profile of each vane. The vanes are then aligned following this optimisation. The quality of the cavity is controlled by RF measurements and the vanes are blocked in position. Reference surfaces on the front, rear and lateral sides are then machined.

These reference surfaces are used for the final alignment after surface treatments and before brazing. A precise alignment is obtained by measuring the gap between adjacent vanes with a simple comparator and with a precision of a few microns. The displacements after brazing are also easily measured by the same means.

HORIZONTAL BRAZING OF MODULE 1

In spite of the fact that we have developed our procedure with the main objective of reducing the possible relaxation movements during the first brazing, we have chosen to use Nimonic springs to help keeping the initial alignment during brazing. Figure 2 shows the brazing fixture used. Along the beam axis, 8 double springs give a charge of 10 Kgf/spring at RT and 19 Kgf/spring at 800 ºC. In the transverse direction, we have used 4 times 6 springs given a charge of 26 Kgf/spring at RT and 19 Kgf/spring at 800 ºC.

Figure 2: Horizontal brazing fixture.

The brazing alloy used for the first brazing step is B-Ag68CuPd-807/810 and the brazing temperature has been 815 ºC. The heating and cooling rates have been limited at 100 ºC/h.

RESULTS

Geometrical Aspects

Figure 3 presents the module after the first brazing. The brazing joints are good without any excessive flow of the braze material inside the cavity.

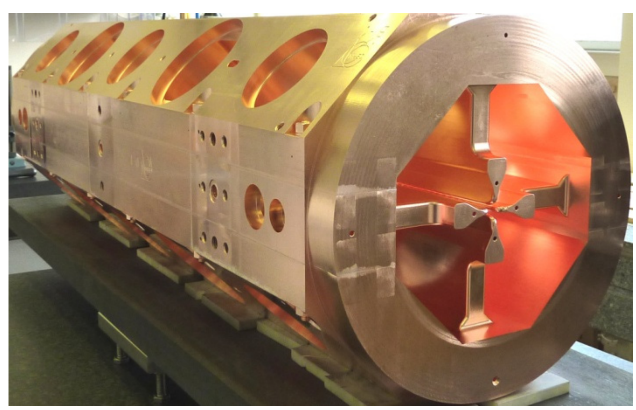

Figure 3: Linac 4 RFQ module after the first brazing step.

The measurements of the relative displacements on the external reference surfaces have shown a longitudinal displacement of 27 µm for one minor vane. The other displacements, longitudinal or lateral, are in the range of 10 µm.

The 3D measurements of the reference holes close to the vane tips show relative displacements in the transverse directions (H + V) in the range of 15 µm for the front (entrance) side and 30 µm for the rear side. Figure 4 shows the differences between the optimized and the measured positions of the front tips reference holes before and after brazing.

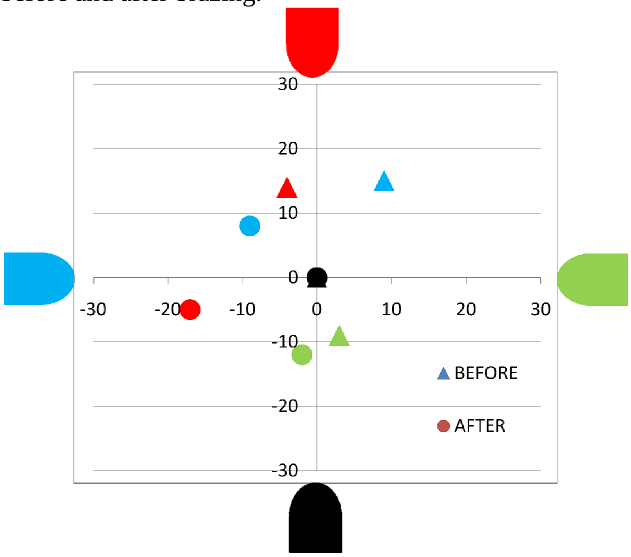

Figure 4: Measured displacements from the optimized position for the reference holes located on the vane tips, front side, before (triangles) and after (circles) brazing (scale in micron). Note that the bottom vane is used as reference and hence its position corresponds always to the optimized ones.

The displacements of the vanes are well below the tolerances for this RFQ: ± 30 µm in H / V directions [1]. Additional measurements have to be done and analysed to understand if we are in presence of pure displacements rather than of deformations of the vanes. Actual results are in favour of the second hypothesis but this must be confirmed yet.

RF Measurement

Systematic RF bead-pull measurements are foreseen during the whole Linac 4 RFQ fabrication process, in order to check that the tight tolerances assigned have been kept.

Bead-pull measurements have been performed before and after the first brazing step, showing that the mechanical fabrication is progressing well within the constraints allowed for optimum field tuning, which will be performed after the final assembly of the three modules by means of the available piston tuners.

The equivalent capacity error profile measured on the first module after the first brazing step remains well bounded within the range [0, 0.01] for the quadrupole component of the electromagnetic field, whereas the error range that could be recovered by the piston tuners is [-0.023, +0.023] for the same component [3].

CONCLUSIONS

The brazing procedure foreseen for the CERN Linac 4 RFQ modules is based on 2 steps, a horizontal brazing for the vanes assembly and a vertical one for the flanges.

The horizontal brazing of the first module has been done after a precise manufacturing procedure including two heat treatments. The main objective of this process has been to reduce as much as possible the constraints introduced during machining.

The results obtained are very promising since only small displacements or deformations have been measured after the first brazing. This demonstrates that a two steps brazing procedure can be successfully used for RFQ modules if a correct manufacturing process is used.

ACKNOWLEDGMENTS

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