LABORATORI NAZIONALI DI FRASCATI
SIS – Pubblicazioni

LNF–05/ 22 (IR)
14 Novembre 2005

FIRST RESULTS ON VACUUM BRAZING OF RF, 11 GHz, LINEAR ACCELERATING STRUCTURES AT FRASCATI LABORATORY.

P. Chimenti[1], V. Chimenti[1], A. Clozza[1], R. Di Raddo[1], V. Lollo[1], M. Migliorati[2], B. Spataro[1]

[1]INFN-LNF Via E. Fermi 40, I-00044 Frascati, Italy

[2] Università degli Studi di Roma "La Sapienza", Dip. Energetica, Via A. Scarpa 14, 00161, Roma, Italy

Introduction

The international scientific community of particle accelerators has an increasing interest in developing new and more performing accelerating structures. The X band linear accelerating cavities are very promising devices to obtain high accelerating gradients.

The aim of this paper is to describe the mechanical and vacuum brazing procedures adopted to realize an 11.4 GHz RF linear accelerating structures [1,2].

Material & fabrication

The material used for the realization of the accelerating structures prototype is Cu OF.

The accelerating structures are a multi cell structure, 9 cells in our case, and are obtained joining together single cells using vacuum brazing technique.

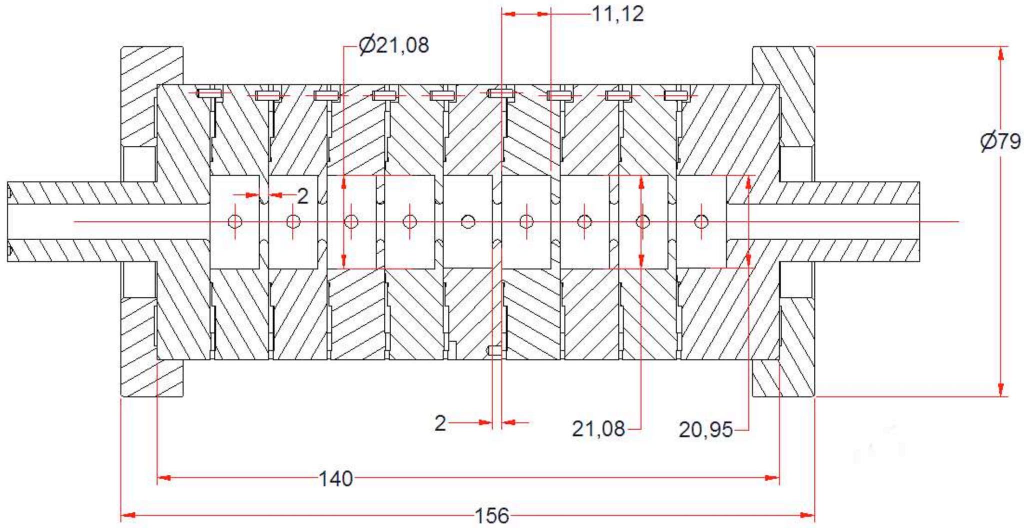

Fig. 1 – multicell structure

At very high frequencies the wavelength becomes very short, so, to satisfy the electromagnetic constrains, the machining of a single cell requires a high mechanical precision (10 micron). This is particularly important for 11.4 GHz structures, as in our case.

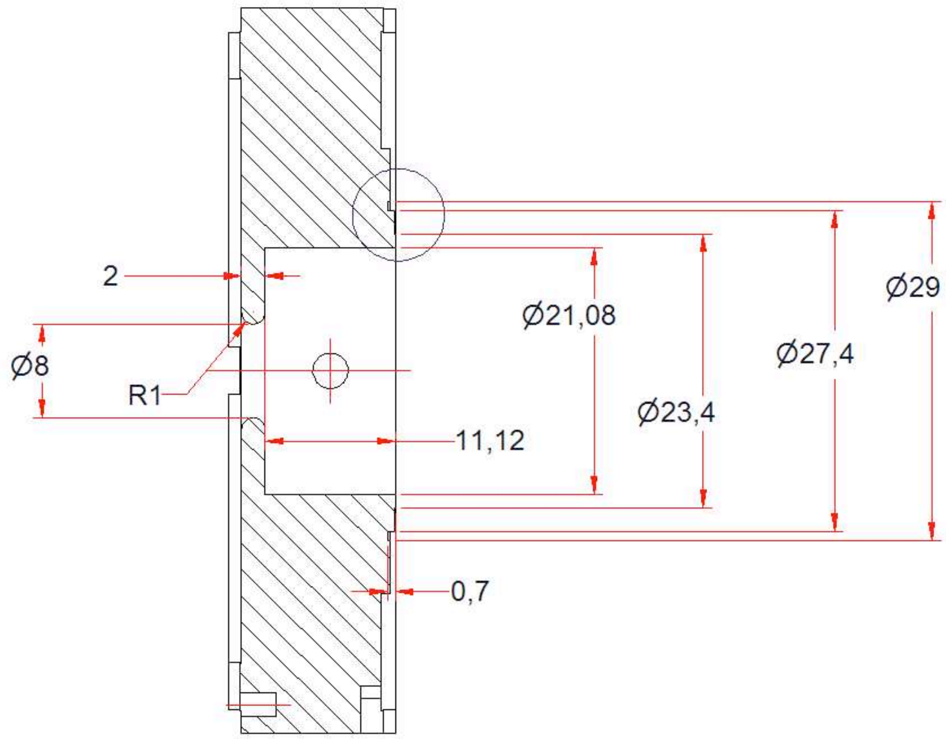

Fig.2 – single cell dimensions

In order to obtain a structure with good electromagnetic behaviour, particular care must be taken for the joining of the single cells, and the subsequent brazing procedure must obviously maintain the prescribed tolerances.

Under these conditions, at Frascati Laboratories of INFN, started an activity aimed at obtaining brazed multicell structures that will be made using the vacuum oven located in the area of the D.A. Vacuum Group.

The aim of the work was to cope with the following items:

1)A good electrical, mechanical and vacuum tight contact among the cells. The necessity to have a good electrical contact is obvious, because we are speaking about an RF X band device. The necessity to have a vacuum tight contact is obvious too, because the structure must operate under vacuum. A good mechanical contact is not so obvious as the previous ones. This need comes from the fact that the total length of a multicell structure is the sum of the lengths of the single cells plus their coupling tolerances. And, taking into account the tolerances needed, this is not so easy to obtain.

2)No diffusion of the brazing alloy inside the cell volume. At the level of the contact area between two cells the adopted clearance must guarantee that there is no variation of the total longitudinal length before and after brazing, as said before, and that there is no flow of the alloy inside the cells, because this would modify the inner volume and therefore the resonant frequency.

3)A contact design able to tolerate temperatures of many degrees (10 ÷ 15°C) over the melting point of the alloy, while respecting the previous points 1) and 2). This is very important because in long structures, as the one described in this paper, the temperature, during the brazing procedure, is not perfectly uniform, and there could be differences of about 10 ÷ 15°C. In other words, long structures do not get to the melting temperature everywhere at the same time. With a proper design of the mating surfaces, the melted alloy, due to the capillary forces, will not diffuse away from the contact area towards the cell.

The profile of the contact surface between two adjacent cells has been chosen in order to satisfy the points 1), 2), 3).

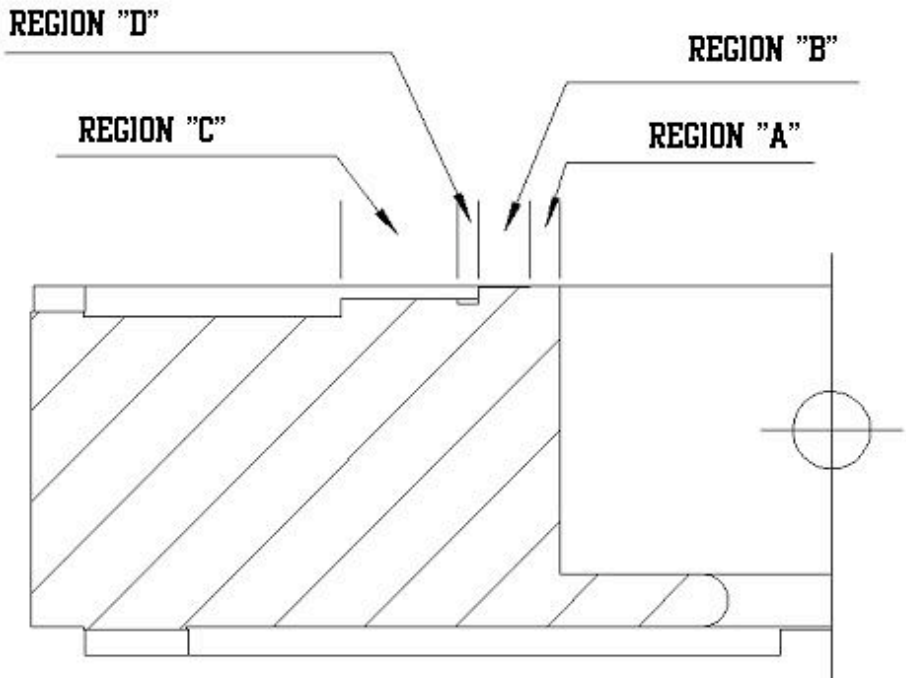

Fig 3 – brazing profile

This profile comes from the experience of the Vacuum Group in this field.

The base point is that the vertical dimension of the contact area (REGION “A”) is simply determined by the mechanical precision of the machining, as requested for the cell.

Considering the fig 3, moving from the inside, the second area (REGION “B”) has a vertical dimension of a few tens of micron and will receive by capillarity the liquid alloy coming from the adjacent 0,6 mm alloy wire that is located in a groove 0.7 mm deep and 0.8 mm wide (REGION “D”). The last area (REGION “C”) that is 0.5 mm deep is for vacuum purpose and to avoid that melted alloy escapes towards outside.

It has to be underlined again that the small clearance of the contact area should stop the liquid alloy from moving toward the inner surface of the cell. This is the BASE POINT to be tested.

Operating conditions

The material used to made the RF cavities is Cu/OF, UNI 5649/71, and the brazing alloy is eutectic Ag/Cu 72/28, 0.6 mm wire whose melting point is 780 °C.

The roughness of the machined parts is about 0.4 μRa. This value is obtained only by machining, using special cutting tools, and avoiding any polishing paste. Sulphur or silicon compounds are not allowed as for cutting fluids.

Cleaning procedures and surface treatments are as follows: all the parts where cleaned using an alkaline solution at room temperature, then copper parts where deoxidized with a hot solution of Citric acid, after that a final rinsing in distilled water was performed followed by drying in a clean air oven at 100 °C.

Vacuum Oven

Immediately after cleaning procedure, the structure to be brazed is mounted inside the oven with its axis of symmetry in vertical position, obviously.

The contact pressure among the cells is obtained only with a 0,5 Kgr weight, without using tie rods.

Two thermocouples are used to control the temperature; the first one is free inside the inner volume of the oven, the second one is directly inserted in a hole drilled in the central cell.

The temperature rise is controlled taking two conditions into account:

- the pressure must be maintained at no more than $1 – 2 . 10^{-5}$ mbar
- the difference between the two temperatures (oven and structure) is kept as low as possible in order to maintain as much as possible thermal uniformity on the cavities.

Evaluation criteria

Three structures were machined and then brazed at different temperatures. The following controls were made after the brazing.

The structure is cut into two halves and the surfaces so obtained are polished. At this point it is possible to see if the alloy has diffused correctly and, above all, if it has filled up completely the contact area <u>without</u> flowing inside the cell.

Dimensional check. Essentially the total length must be measured: it must be the sum of the lengths of the single cells.

Leak test using a Helium leak detector. This test gives an idea about the uniformity of the brazing and obviously is essential in order to put under vacuum the structure.

Results and conclusions

The geometry adopted for the contact area, as in fig. 3, has given good results because the alloy does not abandon the contact area even if the cells remain a long time at high temperature.

Temperatures higher more than 20 °C over the melting point for a time longer than ten minutes were tested. This means that long structures can be easily brazed without the necessity of an accurate (and not easy) temperature control along the piece.

The total length of the structure, as well as its coaxiality, are not modified by the brazing operation (but the result must be tested on long structures).

The use of a weight instead of tie rods to keep in contact the cells during the brazing is simple and effective. Also in this case for long structures precautions shall be taken to garantee the coaxiality.

The Copper cleaning procedure is simple and seems more than sufficient.

The working pressure during the brazing operation, roughly 10^{-5} mbar, is sufficient: Copper comes out from the oven clean and brilliant, this also because the oven has an oil free, high pumping speed vacuum system.

Under the above operating condition, a brazed 9 cells structure has been made. The results of the leak checking procedure are fully satisfactory: no leaks found.

At present the brazed structure is under RF tests.

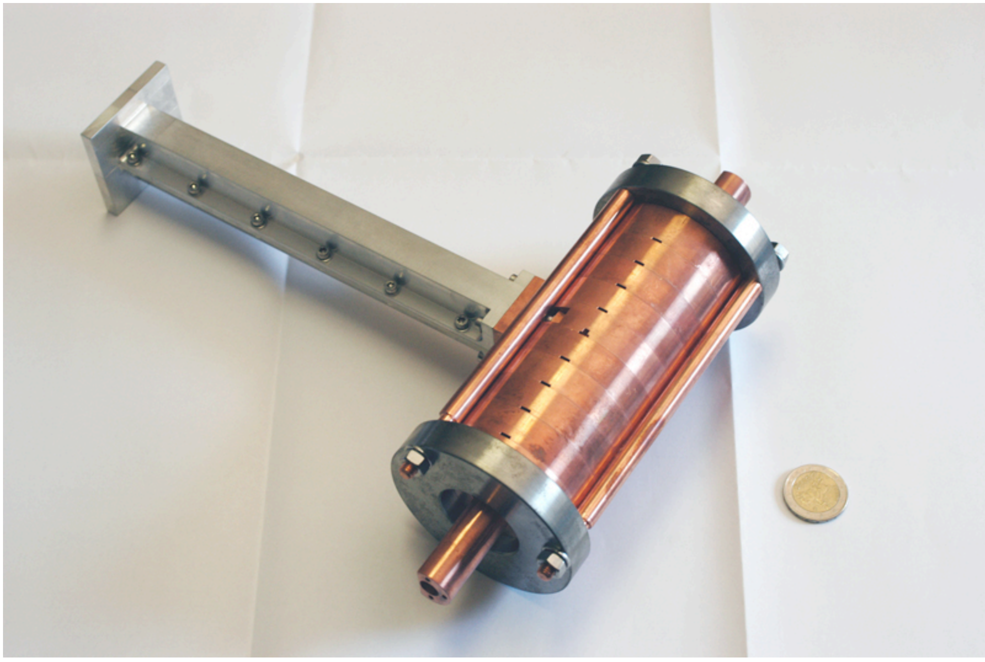

Fig 4. Brazed 9 cell structure.

Future work

Tests on proper supports designed to keep in position long multicell cavities during the brazing must be completed, as said before.

An activity for preparing (machining and brazing) multicell π/2 structures is in progress, first results before the end of 2005.

A fundamental step is to prepare a multicell structure ready to be put under vacuum and with its proper cooling system, in other words ready for the power tests. Preliminary drawings are already prepared together with an analysis of what other Laboratories are doing. This activity will develop during the next year.

Finally a study is started about the possibility to prepare the Copper cells with their iris made in Molybdenum. This particular structure would give the possibility to increase the Electric Field up to a factor of three.

Acknowledgements

Authors would like to thank CECOM (RM) for the high level technological support to this work in the mechanical realization of the multicell structures.

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