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AN INVESTIGATION ON ELECTROFORMING PROCEDURES FOR R.F. 11 GHz LINEAR ACCELERATING STRUCTURES AT FRASCATI LABORATORY

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Introduction

An activity on the design and construction of high frequency, multicell accelerating structures is in progress at Frascati Lab using the Vacuum Brazing Technique. An alternative to the standard machining and brazing procedure is the Galvanoplastic technique of Electroforming.
A study on the possibility of obtaining the same final result following this completely different technique is in progress

General description

The Electroforming is an electrolytic procedure through which a thick layer of Copper, or other metals, is obtained on a core that is subsequently eliminated.
Originally this procedure was used to obtain hollow metal structures, even with large dimensions, for example statues, where the external surface was of interest.
Presently the Electroforming is used to produce special components for the space industry, VHF devices, waveguides and so on.

The procedure consists of the following steps:

1) The core on which the Copper must be deposited is prepared. The external shape of this component will give what is necessary to produce, for example, as said before, a set of special tubes, a waveguide an so on. Machining and surface finishing must be as accurate as requested. Aluminium is generally used because it can be easily machined and polished.
2) The core is immersed in a bath that contains water soluble Copper salts and other special chemical compounds. It is then connected to a negative voltage. Voltage, current density and temperature values are properly set. Some masks are inserted in the bath around the piece in order to make uniform the Copper deposition. If very thick layers of Copper are requested (many millimeters) the core must be taken off from the bath and polished more than one time, in order to guarantee a Cu layer without defects.
3) At the end of the operation the piece is extracted from the bath, washed and introduced in a special chemically aggressive bath for Al (if Al has been used) but not for Copper. In this way the core is eliminated and a hollow structure remains with the requested shape: in our case a multicell cavity structure.

Other parameters of interest are:

a) Deposition rate.
For complicated shapes only one micron per hour is used, in order to guarantee a uniform shape. This was the case of our first prototype.
At Frascati, in the future, a reasonable simple shape will be adopted, in order to shorten the deposition time. Standard values of the order of 1 micron per minute can be obtained.

b) Roughness.
The Al core can be easily finished to a roughness of 0.4 micron Ra or better.
If a lower roughness, close to a mirror finishing, will be requested, it is not a problem to prepare the Al core, but it is more difficult to maintain the finishing during the special chemical treatement of the core surface, performed for Electroforming and necessary to have a good Copper adhesion. In this case it is helpful to put a thin layer of Gold (for example by sputtering) on the Al surface. This can avoid the chemical corrosion of the Aluminium.

Main features of the Electroforming procedure

The Electroforming procedure allows to obtain a linear accelerating structure in one piece avoiding the expensive and not easy to do brazing procedure. No vacuum leaks can appear also

after a prolonged use at high RF power (a leak could appear after repeated thermal shocks on a brazed structure).
The core can be machined, finished and controlled in an easier way.
The absence of brazing planes where the brazing alloy can be present avoids any possible discontinuity of the structure along the axis. This means that only Copper is seen by the electric field.
The machining of the piece can not be avoided because at the end of the Copper deposition, after having eliminated the Aluminium core, the structure must be machined to give it a proper external shape and, above all, to prepare it for the water and the electric field connections.
The tuning of a RF structure can be obtained through different ways. For the first brazed structure made in Frascati the way was to locate a threaded tuner on each cell, moving it with a screwdriver to obtain the correct frequency. Threaded holes on each cell have been prepared before the brazing. This cannot be easily made on an electroformed structure, as it will be said at the end of this paper.
The alternative is to drill and thread the holes on the cells as soon as the electroformed piece is completed, but there is the possibility to introduce small Copper chips inside the cells during the drilling operation that cannot be safely eliminated.
A third way is the way generally adopted for tuning multicell structures and it consists in modifying the volume of the cells using a proper device. At Frascati Lab this procedure will be followed both for brazed and for electroformed structures, due to its simplicity and safety.

Work at Frascati Lab

The multicell structure to be made by Electroforming is shown in fig. 1.
In fig. 2 the multicell structure made by electroforming technique is shown. It is possible to see the surface that separates the Copper (outside) from the hollow volume where the Electromagnetic field is present.

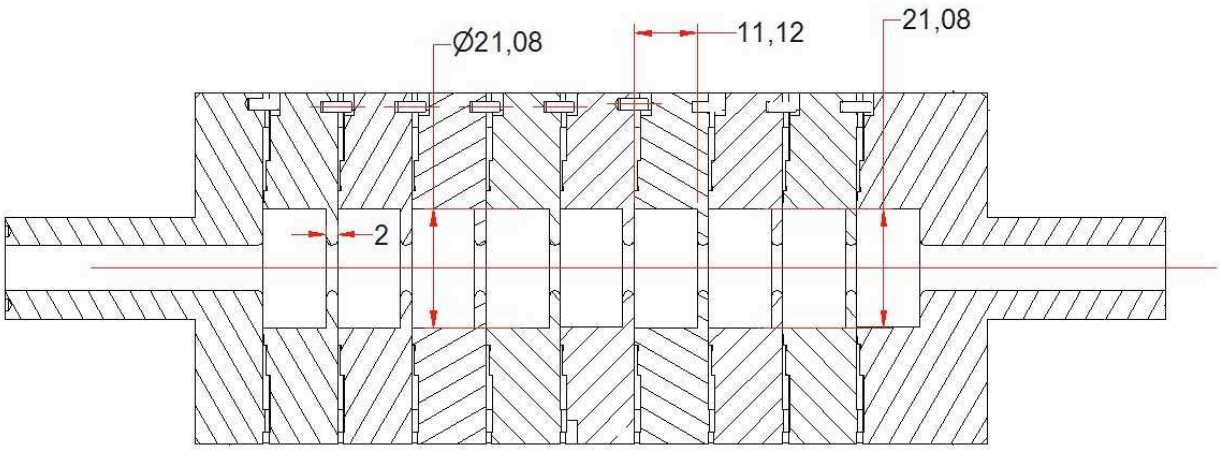

Fig. 1: Multicell structure.

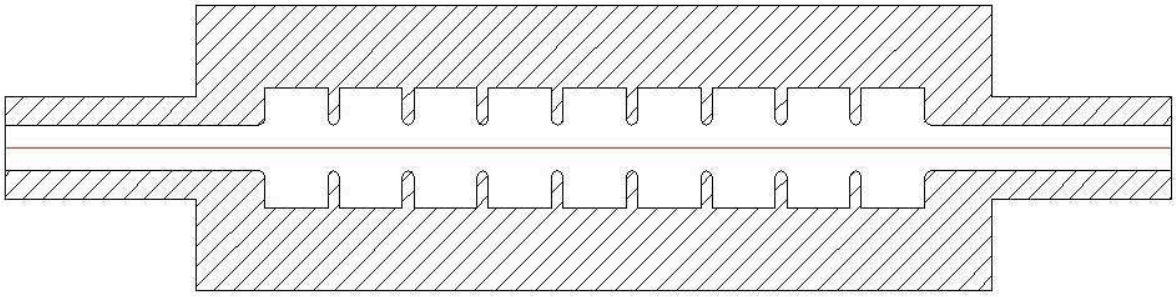

Fig. 2: Electroformed structure.

Referring to fig. 2, it is evident that the Copper ions have difficulty to reach the iris profile during the galvanic operation, due to the depth of the iris respect to its thickness. In order to cope with this problem a hybrid structure for the core has been studied and designed and the result is shown in fig. 3 where the volume of the cells is represented by an Al cylinder and the iris are made directly of Copper. The external shape of this device, the core where Al and Cu alternate, will be covered by Cu atoms without any problem.
Finally a tentative to create the threaded holes by Electroforming for the tuners has been made. For this reason in fig.3 some threaded Al cylinders appear on each cell.

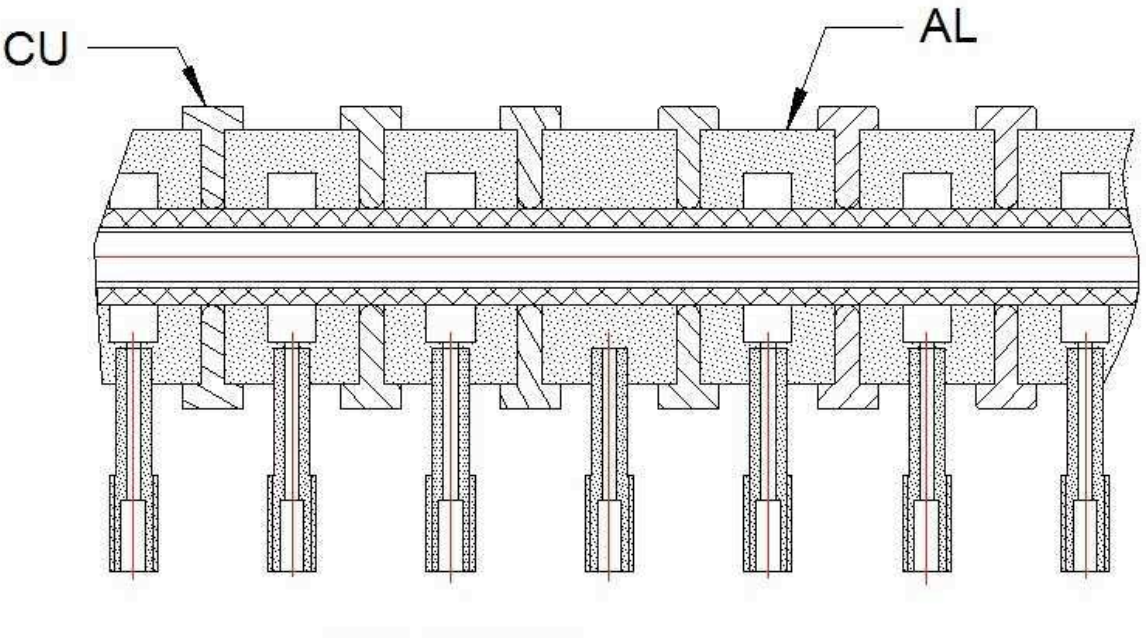

Fig. 3: Core for Electroforming operation.

Moreover, the feeding coupler will be connected at the central cell and the relative Al core shape is under study.
The structure of fig.3, the core, has been obviously prepared following the directions of the specialists of the galvanoplastic company chosen for this task.

Results

Following the above considerations a fully Al core for a 3 cell structure has been prepared and sent to the firm for the Copper deposition.
In fig. 4 a section of the prototype obtained by Electroforming can be seen, cut with a plane passing through the central axis and the axis of the tuners. One of these three cells has been cut away.

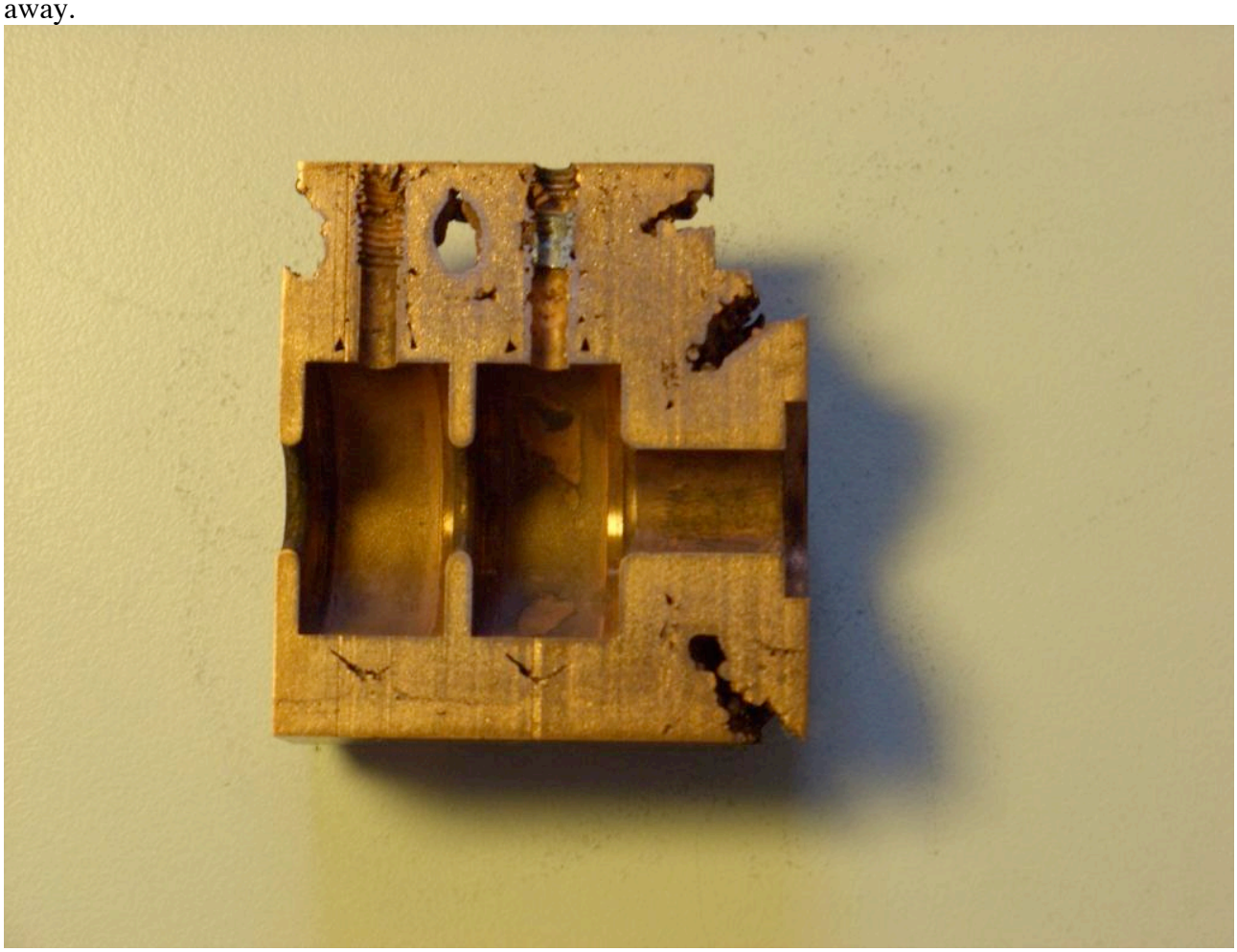

Fig. 4: Prototype obtained by electroforming procedure.

Comments:

a) Roughness.
The inner surface of the cavities seems to have copied the good finishing of the Al surface. Nevertheless an accurate measure of Ra must be performed, first on the core surface and then on the Cu inner surface of the cavities. This point shall be the base point of the future activity.

b) Tuners.
The tentative to obtain the tuner holes by Electroforming already threaded on each cell, as said before, see fig.3 and 4, has not given a good result, because the thread and the finishing are not of good quality. The way to obtain a proper tuning of the structure through a small deformation of the cells will be adopted.

c) Dimensions.
The dimensions of the Copper structure are a copy of those of the core. This must be verified on long structures expecially if the bath for electrodeposition has to work at high temperature.

Future work

The roughness of the surface is at present the main point to work on. For this reason some Aluminium monocells have been prepared in order to send them to the galvanoplastic company for the Copper deposition.
The finishing of the cells has been prepared with different procedures and in any case with a very low level of roughness: values of 0.2 micron Ra have been obtained.
The Cu cells, prepared with the standard procedure, will be tested in order to compare their roughness to the Al ones. In case of necessity, other procedures, as already said, can be activated in order to prepare the Al surface.
Finally, as soon as the surface problems will be defined, a multicell prototype will be prepared.

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