A NEW METHOD FOR FORMING SEAMLESS 1.5 GHZ MULTICELL CAVITIES STARTING FROM PLANAR DISKS

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Abstract

An original technique has been developed at LNL for the preparation of seamless cavities. Without Electron-Beam Welds, 1.5 GHz multicell cavities can be simply formed by lathe-spinning a planar disk. Niobium, Copper and Aluminum can be easily manufactured. Depending on the material properties and on the execution procedure a very limited number of annealings is needed. Due to the high quality of internal surface, to the simplicity of execution, to the low costs and to the short time of the process, the technique is highly competitive respect to the traditional way of electron-beam welding together half-cells and respect to new techniques as for instance hydroforming.

1. INTRODUCTION

Regardless of whether cavities are made of bulk Niobium or Niobium-coated Copper, the standard construction technique consists in Electron Beam (EB) welding together half-cells produced either by deep drawing or by spinning. Since alternative techniques, as for instance hydroforming, have been developed only up to the level of prototypes and not yet to the level of industrial production, the EB welding of half-cells is the only manufacture procedure well-established for an industrial scale. Unfortunately even if such technique is highly reliable from the point of view of a quality control, we cannot say -especially in the case of high Residual Resistivity Ratio (RRR) Niobium- that it is the most convenient from the economical point of view: the material swarf is not negligible and it increases sensitively the construction prices, but above all EB welding is a costly operation. Just for a better understanding, indeed at least 19 EB welds are needed, for a 1.3 GHz nine-cell resonator of the type investigated for the new generation of linear colliders (fig.1). Moreover the quality of the weld is always worse than the one of the starting material quality, depending of the vacuum degree achieved in the EB vacuum chamber.

2. TECHNIQUES ALTERNATIVE TO THE STANDARD

A big effort is dedicated to the development of alternative techniques to build superconducting cavities able to sustain higher accelerating fields, but much less expensive than nowadays.

An alternative fabrication process for multicell resonators is for instance the one described by INTERATOM [1]. Half-cells are cold-formed from Niobium-clad Copper sheets and then welded together. Pipe cooling rather than bath cooling is provided by Copper snakes welded to the external of the cavity.

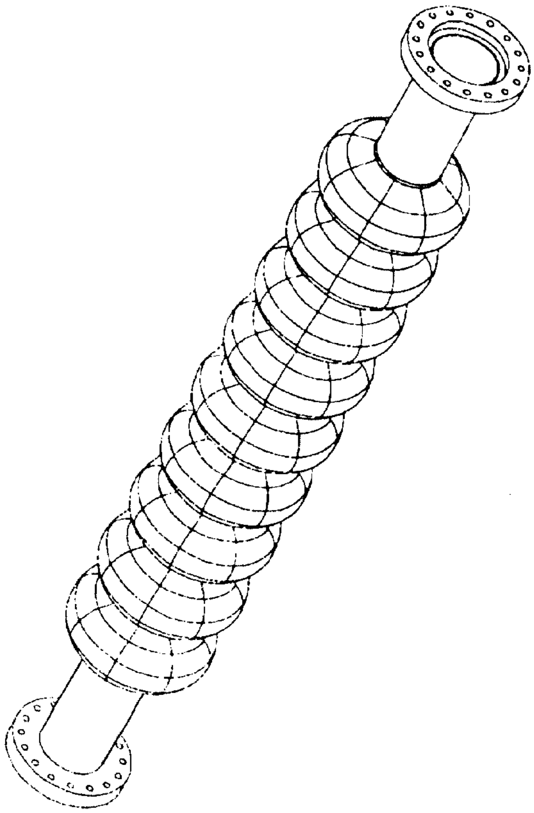

Fig.1 View of a nine cell 1.5 GHz resonator.

Possibilities of manufacturing cavities avoiding EB welds were envisaged since more than ten years. Fancy examples of seamless cavity preparation are reported in literature. One of them [2] consists in the preparation of an aluminium pattern of the precise shape of the multicell cavity interior. The external surface of such pattern is brought to a high degree of finishing by standard mechanical techniques. The entire set is coated with Niobium by EB evaporation. Subsequently a thick Copper layer is electroformed in a proper galvanic bath and the Aluminum is dissolved in a solution of boiling caustic soda. Such a process in our opinion does not take into account that the first layer of the Niobium film just grown on Aluminum will be remarkably stressed, it will be a dirty interface between Niobium and Aluminum, so the first layer should be removed in order to have low surface resistance.

Explosive forming has also been investigated for making a seamless cavity from a Niobium tube [3], but unfortunately with no encouraging results due to the stress rate dependence of the % elongation of Niobium.

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Tubes hydroforming was a method so far applied successfully both to Niobium [3] and to Oxygen Free High Conductivity (OFHC) Copper [4]. Just on Copper reliable multicells resonators are obtainable with a combination of swaging and hydroforming steps with a minimum number of annealings.

By repeated intermediate annealings and bulging a cavity resonator 100 mm at both cut-off tubes and 260 mm at the equator was manufactured from a welded Niobium tube by Furukawa Electric Co. [5]. By deforming outer diameter by more than 5%, they report that the structure is recrystallized in the next annealing, and the structure of the weld zone and raw tube is made uniform. Thus the next bulging is made easy, and the occurrence of cracks during the work can be suppressed.

Other two original methods for manufacturing seamless cavities are reported by this same Japanese firm. The former method asks for coating an Aluminum pipe by a thin film of Niobium. The structure is coated by a Copper layer and the whole "sandwich" is expanded to the desired form by hydroforming. Thereafter the internal pipe is extracted by melting Aluminum.

The latter method is a kind of simplification of the previous since the Niobium film is directly sputtered onto a substrate that has directly the form of a cavity. Then the process proceeds as before, with the advantage of not submitt the Niobium film to hydroforming.

3. SPINNING SEAMLESS CAVITIES

We developed a new method for forming seamless monocells and multicells of Copper, Aluminum and Niobium by cone spinning a flat disk onto a suitable mandrel [8]. The technique is widely described in previous papers [9-10] and primarily consists in a rotary-point method of extruding metal pressing it against a mandrel rotated by the headstock of a lathe. A metal disk is firstly spun into truncated-conical shape onto a preform. Subsequently the final shape is obtained spinning the material from the external, onto a mandrel that exactly reproduces the shape of the cavity interior. Hence the truncated cone piece is spun against the mandrel looking for the closest fit of the metal to the mandrel.

The mandrel is made collapsible so it can be extracted from the cavity after forming. By this process the metal is made flowing under plastic deformations in a bidimensional space. In this way, rather high % reduction can be achieved without any buckling or cracking. This method found for the forming of monocells has been successfully applied in iterative way for the construction of seamless multicells. No intermediate annealing is needed when forming pure Aluminum. Actually we formed 1.5 GHz Aluminum seamless nine-cell cavities by cone spinning starting from a disk of about 800 mm diameter in a few hours operation without performing any annealing. Thickness uniformity along one meridian is better than a factor 2. Around azimuth the thickness is uniform within 20%. By the same technique we also built Copper and Niobium monocells. Copper is a more difficult material to cold-work than Niobium because it hardens very easily. However at the moment we are working to the possibility to prepare Copper and Niobium multicells without any intermediate annealing.

Fig.2 A longitudinal crack appearing on the internal surface of cavity at the level of the second formed iris. The total width of the photograph is 100 μm.

Niobium coating of such seamless Copper cavities as well as low temperature radiofrequency measurements of our seamless Niobium cavities, will be performed only on the best obtained prototypes. It is worthwhile to start with fine scale measurements only after having optimized our forming process, and solved fundamental problems. Better thickness uniformity is still obtainable; depending of the process steps and operation parameters, the "orange peel" at level of second spun half-cell (at the iris of the second cut-off) can be much reduced if not even eliminated.

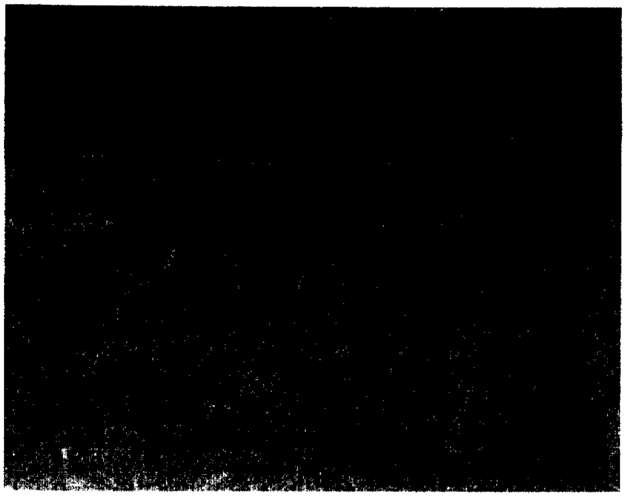

Fig.3 Section of the resonator wall. In order to put in evidence cracks without damaging the sample when cutting, the surface has been nickeled with 20 μm film.

In this framework, metallurgical exams are a good start for attacking the problem. Hence one Copper monocell was cut along two meridians and the relative sector was examined by Scanning Electron Microscopy. The internal surface appears more or less damaged depending on the position. The best surface quality is obtained at the equator, while the iris of the second cut-off is the worst place exhibiting a sort of net of longitudinal cracks (fig. 2).

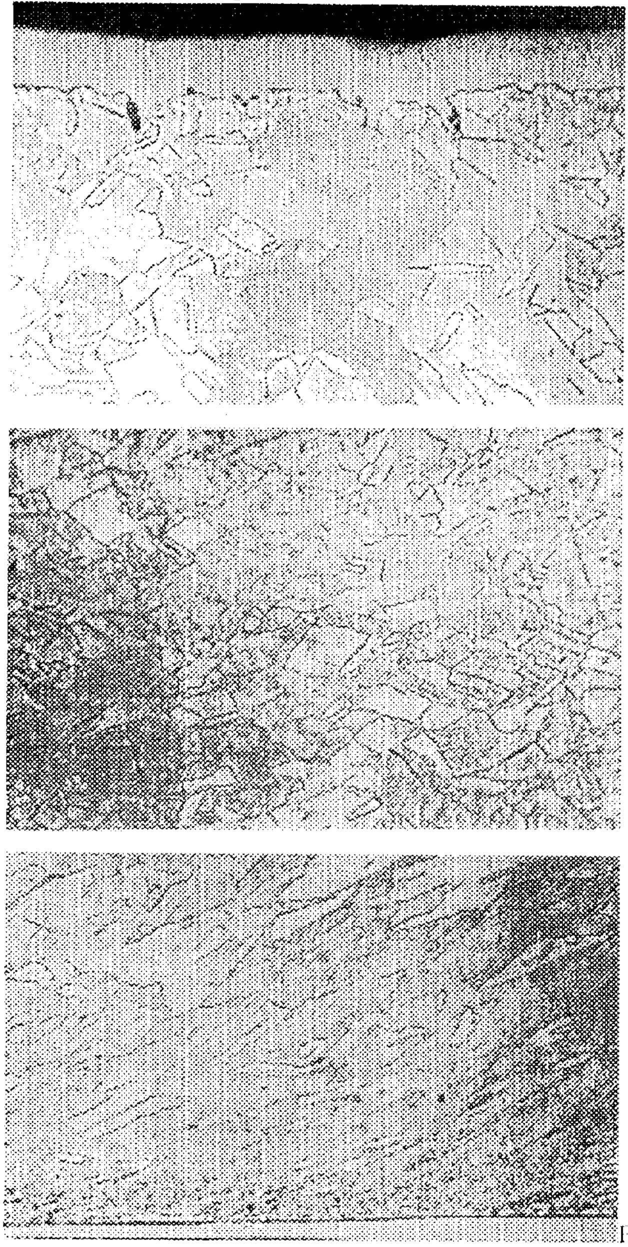

Fig.4 Micrographs of the cavity wall cross-section at 500 magnification. From up to down, a 1.4 mm Copper sample is photographed along thickness from the resonator interior, to the medium, to the external..

However the maximum depth of such cracks is of the order of 30 μm. (fig. 3). Indeed a layer of approximately 100 μm is removed when performing mechanical and electro-chemical finishing of the cavity internal surface. Niobium seems to behave similarly to Copper respect to this problem, even if it does not harden as Copper. Aluminum cavities show a much better internal surface. Moreover the Orange peel seems to be not dependent of the particular cell formed. It is systematically present at the level of each iris, being absent at the equator.

Just that makes cone spinning very intriguing respect to other methods. Indeed just after having formed one cell and half of the subsequent, it is possible to mechanically finish the internal surface around the iris. By this few minutes operation, multicells can be produced having a much less significant roughness before undergoing chemical process.

However, because the material is spun from the external, the internal surface seems to be the less damaged, even if cracks are born on it. As we already expected from literature, the hardening of the surface is maximum at the surface in contact with the spinning tool. The best proof of this is given by section micrographs of the cavity wall (fig. 4). Grains are larger at the internal part, became smaller in the middle of section and are completely stretched at the external.

4. CONCLUSION

We have found a cold-forming method for producing seamless multicells starting from planar disks. The preparation of a nine-cell cavity takes less than one day. Thickness uniformity is up to now within a factor two. Due to the strong deformations applied to the spun material, thinner wall resonators could be produced due to the hardening of material. However further investigations are needed for understanding the optimum thickness. Unexpected problem of mechanical nature could appear.when firing such a seamless Niobium cavity or even when tuning the cavity. The production of seamless cavities also requires the development of electrochemistry and chemistry for polishing a multicell resonator. Only after having clarified these points, sputtering and rf measurements will have sense.

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