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COMPARISON OF ELECTROMAGNETIC PROPERTIES DURING FABRICATION OF COPPER AND NIOBIUM PROTOTYPES OF 325 MHz COAXIAL HALF-WAVE RESONATOR

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Abstract

The main fabrication stages of niobium and copper prototypes of coaxial half-wave resonators (HWR) operating at frequency 325 MHz for the Nuclotron-based Ion Collider fAcility (NICA) injector are presented and discussed. Results of intermediate measurements and electromagnetic properties control for niobium and copper cavities of equivalent geometrical characteristics are compared and analyzed. The comparison of electromagnetic properties of Cu- and Nb-prototypes allows estimating specific features and differences of intermediate "warm" measurements of niobium and copper cavities. The presented results will be used for further development and production of superconductive niobium cavities with a similar design for the NICA-project.

INTRODUCTION

The fabrication process of superconductive cavities for high energy particle acceleration consists of many intermediate stages including sheet niobium purity control, hydraulic stamping, rolling, electron beam welding, polishing, etc. The quarter- and half-wave resonators (HWR) with integrated helium vessel including a large number of components and their manufacturing process become even longer and complex. Usually, the cavity production process is started with the fabrication of a copper prototype with identical geometrical parameters. The detailed description of the HWR copper prototype operating at frequency 324 MHz was presented in our recent work [1]. The present communication is devoted to a comparison of electromagnetic characteristics during fabrication of Nb and Cu HWR of equivalent geometrical characteristics. The model of the HWR niobium prototype is presented in Fig. 1. This cavity is designed and developed for the Nuclotron-based Ion Collider fAcility (NICA) injector.

The cavity in Fig. 1 was designed in a classical coaxial half-wave configuration [2, 3]. The general difference from the copper prototype considered in [1] lies in the design of the cavity's flanges. In the copper prototype, stainless steel (AISI 316) CF40 flanges were electron beam welded to the cavity. For Nb-prototype, we used NbTi47-based [4] flanges and hexagonal AlMg alloy gaskets. This type of flanges allows performing electron beam welding with a cavity made of high purity niobium (RRR=300, produced by Ningxia) and with an integrated helium vessel made of titanium.

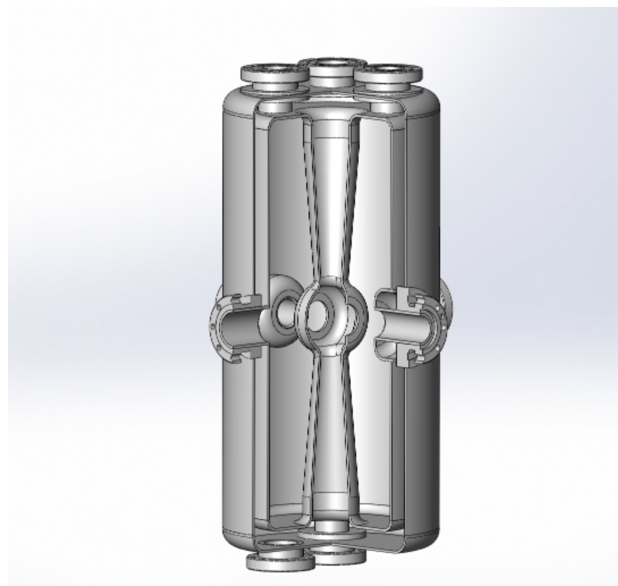

Figure 1: The sketch of the 324 MHz niobium HWR prototype model.

The most important geometrical parameters of considered cavities are inner height H and accelerating gap g. They may be varied during the fabrication process to achieve the goal resonant frequency f of the finally produced cavity. In the next sections, we will discuss the most important results related to frequency control during the fabrication of Cu and Nb HWR prototypes.

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FREQUENCY CONTROL DURING FABRICATION

During fabrication of HWR the resonant frequency of the cavity, assembled but not welded yet, should be organized. The deviation from the goal frequency may be partially compensated by varying cavity height H and accelerating gap g. The cavity volume may be assembled from six parts (see Fig. 2(a)) using a special fixture (see Fig. 2(b)). This fixture allows to fix all parts together without penetration of any external object inside the cavity volume and provides intermediate resonant frequency control at all production stages. The developed fixture is also suitable for electron-beam welding without disassembly after RF measurements (see [1] for detailed description).

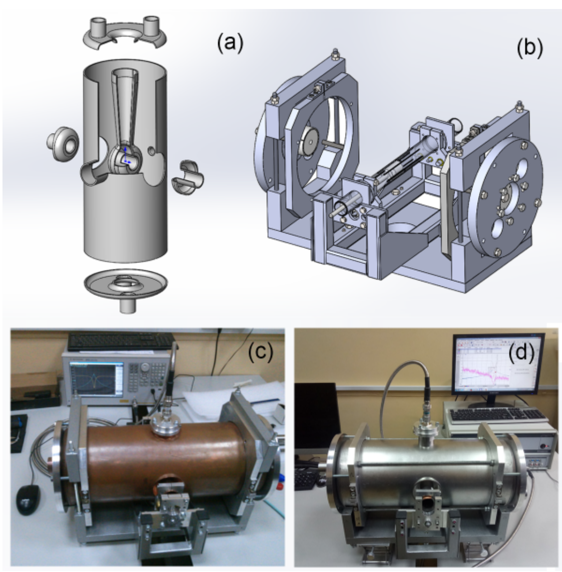

Figure 2: (a) Principal HWR components; (b) fixture for welding and intermediate RF measurements; assembled (c) copper prototype and (d) niobium prototype.

In Fig. 2 (c) and (d) are presented assembled copper and niobium prototypes during intermediate frequency measurements, correspondingly.

At the first manufacturing stage, the inner and outer conductors of HWR are produced with increased height H. Usually, several trims of these parts are performed, the resonant frequency is measured and the sensitivity coefficient $\alpha_H = df/dH$ is determined. Using α_H the final cavity height is estimated and all parts in Fig. 2(a) except for two beam ports are welded together. During the first welding stage also an additional important experimental parameter β should be determined. This parameter is associated with shrinkage of the weld and with the change in the height β_H and frequency β_f of the resonator before and after welding.

At the second stage the welded central part is assembled with two beam-port cups and the resonant frequency sensitivity α_g to the accelerating gap g is estimated. The fixture Fig. 2(b) allows to precisely change the position of beam-port cups along the beam axis and estimate the optimal value of acceleration gap g to achieve the goal frequency. After that, all parts are EB-welded together and the production of the central part of HWR is finished. During the final EB-welding stage, the important parameters γ_l and γ_f related to the change in the accelerating gap and frequency of the cavity before and after beam ports welding are estimated. All experimental results of resonant frequency measurements of copper and niobium prototypes are presented and compared in the next section.

THE EXPERIMENTAL PARAMETERS OF FABRICATION

The most important results and comparison of frequency control during fabrication of Cu- and Nb-prototypes are presented in Fig. 3. All intermediate measurements were performed at room temperature. The first two stages were focused on cavity height adjustment then the frequency is tuned by changing the accelerating gap g. For comparison of two prototypes, the frequency measurements in Fig. 3 were performed in the equivalent conditions (i.e. the power and field-probe antenna inputs penetration depth was the same at all stages (see details of measurements conditions in [1]).

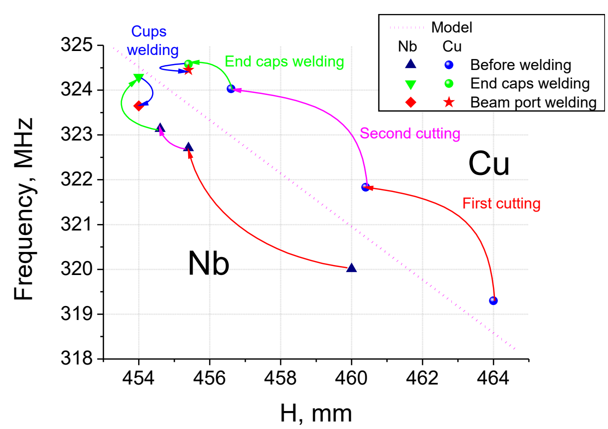

Figure 3: Resonance frequency change during intermediate fabrication steps of the central part of copper and niobium prototypes.

From Fig. 3 we can see that at the first stages the frequency dependence on H of both Cu- and Nb-prototypes is quite similar. The frequency deviates significantly from the expected value after the end caps welding stage for Nb-prototype. We associate this effect with improved electrical contact between the cups and the inner and outer conductors after welding. Also from Fig. 3, we can see that the shrinkage during beam port cups welding is much more pronounced for Nb-prototype.

The eigenfrequency (i.e. frequency of the cavity only with field probe antenna with minimal possible penetration depth) change during intermediate fabrication steps of the central part of Nb-prototype is presented in Fig. 4.

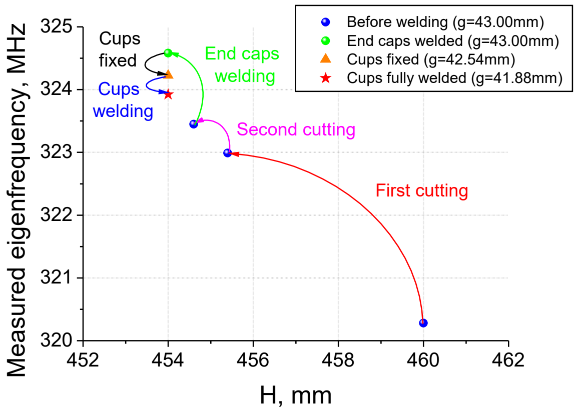

Figure 4: Eigenfrequency change during intermediate fabrication steps of the central part of the niobium prototype.

Fig. 4 is generally similar to Fig. 3, the presented experimental eigenfrequency measurements will be used for the further production of series of 324 MHz resonators. The most important experimental parameters related to the fabrication of HWR prototypes are presented in Table 1. The data in this table is related to standard measurements conditions [1] for the copper prototype and to eigenfrequency measurements for the niobium prototype.

Table 1: The Experimental Parameters Related to the Fabrication of HWR Prototypes

	α_H, kHz/mm	α_g, kHz/mm	β_f, kHz	β_H, mm	γ_f, kHz	γ_l, mm
Cu	-578.9	636	550	-1.2	-77.5	-
Nb	-587.8	609	1130	-0.6	-304	-0.67

From Table 1 one can see that Nb-prototype is much more sensitive to the EB-welding process in comparison to the copper cavity. The difference between estimated coefficients α_H, α_g, and β, γ may be associate with the contact effects, which are more pronounced for cavities fabricated from niobium.

CONCLUSIONS

The experimental parameters most important for copper and niobium 324 MHz HWR prototypes fabrication process are presented. The experimental data shows that the Nb-prototype is much more sensitive to the EB-welding process in comparison to the copper one. The presented results will be used for the further manufacturing of niobium cavities for the NICA project.

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