VERTICAL TEST RESULTS ON ESS MEDIUM BETA ELLIPTICAL CAVITY PROTOTYPE

Enrico Cenni#, Guillaume Devanz, Xavier Hanus, Franck Peauger, Juliette Plouin, Dominique Roudier, Luc Maurice, Fabien Eozenou, Christophe Servouin, Stephane Berry, Pierre Bosland, CEA Saclay, Gif-sur-Yvette, France
Christine Darve, ESS, Lund, Sweden
Gabriele Costanza, Lund University, Lund, Sweden

Abstract

The ESS elliptical superconducting Linac consists of two types of 704.42 MHz cavities, medium and high beta, to accelerate the beam from 216 MeV (spoke cavity Linac) up to the final energy of 2 GeV. The last Linac optimization, called Optimus+ [1], has been carried out taking into account the limitations of SRF cavity performance (field emission). The medium and high-beta parts of the Linac are composed of 36 and 84 elliptical cavities, with geometrical beta values of 0.67 and 0.86 respectively. This work presents the latest vertical test results on ESS medium beta elliptical cavity prototypes. We describe the cavity preparation procedure from buffer chemical polishing to vertical test. Finally, magnetic probes (Fluxgate) were installed on the cavity to determine magnetic field background during vertical test. The latest vertical test results showed that the cavity design performance is beyond requirements.

INTRODUCTION

CEA-Saclay is in charge of developing and manufacturing six medium beta elliptical cavities [2] for the superconducting section of ESS Linac. Four of these cavities will be installed in a cryomodule prototype used as demonstrator [3]. Next, 5 high beta cavities [4] will be manufactured and installed (4 of them) into a cryomodule for testing.

As of September 2016, all 6 medium beta cavities have been manufactured, 2 were tested and are ready for helium tank integration. The remaining 4 will be soon delivered to be polished by means of acid etching (buffer chemical polishing). Figure 1 shows a section of a medium beta cavity equipped with the helium tank.

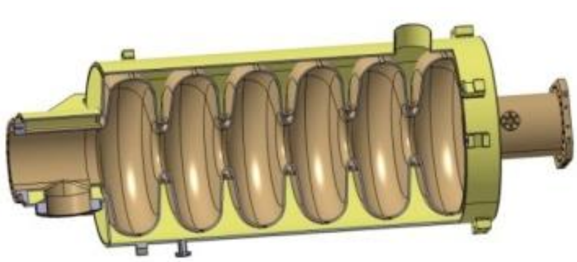

Figure 1: Medium beta elliptical cavity equipped with helium tank (section view).

#enrico.cenni@cea.fr

Table 1 presents all the relevant parameters concerning medium beta cavities design and working conditions.

Table 1: Medium Beta Cavity Design Parameters

Parameter	Value
Frequency	704.4 MHz
Length	1258.8 mm
# cells	6
Operating temperature	2K
Beta	0.67
Nominal E_{acc}	16.7 MV/m
Q_0 at nominal E_{acc}	$>5x10^9$
E_{pk}/E_{acc}	2.36
B_{pk}/E_{acc}	4.79 mT/(MV/m)
G	196.63 Ω
Cell to cell coupling	1.2%

CAVITY MANUFACTURING AND PREPARATION

Six cavity prototypes have been manufactured following a dedicated procedure [5].

In Table 2 are shown the average deviations between the measured and simulated length and fundamental mode frequency, for the 6 manufactured cavities.

Table 2: Cavities Manufacturing Deviation Summary

Parameter	Average deviation respect computed values
Length	0.767 mm
π-mode frequency	0.292 MHz

Preliminary results on accelerating mode frequency and length show that the manufacturing process is accurate and reliable, especially into evaluate the welding shrinkage. This allowed us to have a precise estimation of the cavity frequency and length. On the other hand, field flatness measurements just after welding, showed to be different among the two first cavities. P01 had a 56.8% field flatness while P02 had 89.1%. Our goal is to tune all cavities with a field flatness of 95% before the helium tank integration. A dedicated tuning machine was designed to achieve this task, each cell can be tuned independently during the same tuning process.

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EXPERIMENTAL RESULTS

Buffer Chemical Polishing (BCP) Study

Great effort has been put into BCP study and optimization, some encouraging results have been obtained recently on the second cavity prototype. The study was originated by the necessity to clarify the first vertical test behaviour. The Q-E curve suggested that a Q-disease occurred, and the cavity performances could not be improved even after warm-up and cooldown at rate of 4K/min. The surface resistance and the Q-E curve remained almost identical despite the warm-up and the change of cooling speed.

A close analysis of the BCP process, in particular of the cavity surface temperature during the polishing, was carried out and has been reported in [6]. For the sake of comprehension, a brief description is shown in figure 2, which shows the temperature measured on the cavity surface with respect to time. Relevant moments during BCP are marked on the graph. Two rapid transient in temperature are observed, at the beginning and at the end of the BCP process. The first one is attributed to the moment when the acid begins to etch the Niobium and the latter to a residual acid layer. In the mid-section of the graph, a temperature rise with a slope similar to the one measured in the acid tank can be observed.

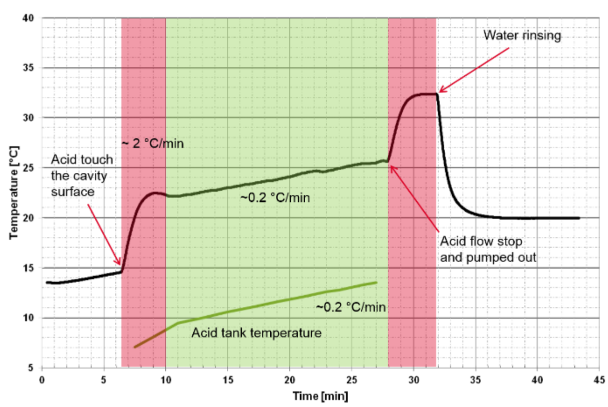

Figure 2: Temperature measure on cavity surface during BCP.

Figure 3 shows the temperature on cavity surface at different location with respect to time. It is worth noticing that on the same cell, temperature differences in the range of 10-15°C with respect to locations symmetric to the equator, namely positions 5-1 and 4-2 are measured. The observed differences in temperature are consistent with the removed material measured by means of ultra sound, that is hotter spots experienced more etching than colder ones. To counter-balance this phenomenon, the cavity is turned upside down after half of the BCP process is performed. Finally the ratio between the most etched spot and the lowest is a bit more than 2.

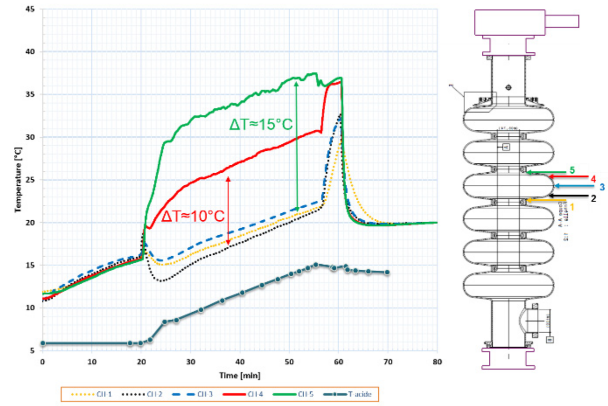

Figure 3: Temperature measurements on cavity central cell surface during BCP, different colours correspond to different location as depicted in the sketch on the right.

Vertical Test Results

So far, two cavities have been polished and tested. In table 3 are shown different phases and vertical test results. For the second prototype (P02) we performed only "cold" BCP, the process was stopped as soon as the temperature in the acid tank reached 15°C.

Table 3: P01-P02 Preparation and Test History

P01	Notes	P02	Notes
BCP (1:1:2.4)	200µm	BCP (1:1:2.4) $T_{acid\text{-}tank}$ (<15°C)	200µm
Vertical test (#1-2)	Q-disease, R_s@2K≈200nΩ	Vertical test (#1)	Q-disease, R_s@2K≈30nΩ
Heat treatment	600°C (10 hours)		
Vertical test (#3)	R_s@2K≈20nΩ		
BCP (1:1:2.4)	20µm		
Vertical test (#4)	R_s@2K≈10nΩ		

Most of our effort have been dedicated to understand and optimize all the process involving the first prototype (P01) preparation. This allowed us to utilize P01 as reference for the remaining cavities in the pre-series.

Figure 4 shows the performance improvement since the first BCP that removed 200µm, at that stage the cavity had a typical Q-disease Q-E curve, performance were drastically improved by means of heat treatment at 600°C for 10 hours.

Finally, the performances were improved and even overpassed the requirements after 20µm removal with BCP, figure 5. In figure 6 is shown the surface resistance (R_s) measure with respect to temperature and measured after the same preparation phases.

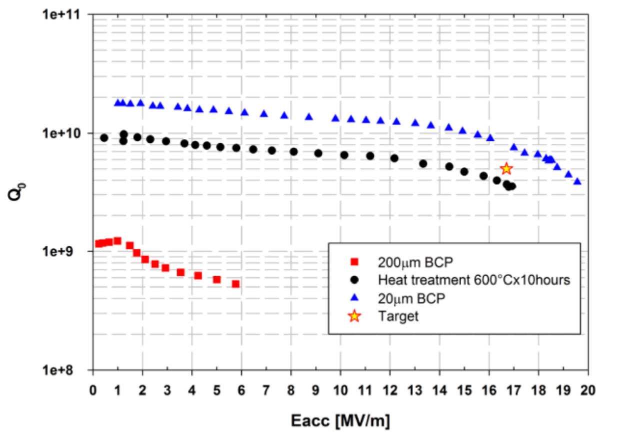

Figure 4: Performance improvements through different preparation stages.

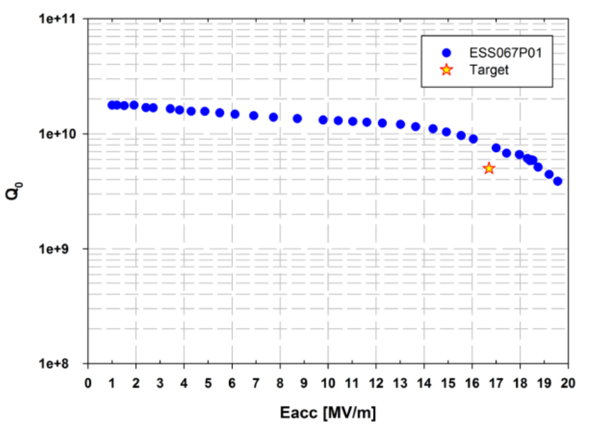

Figure 5: Vertical test #4 cavity P01 performance exceed requirements.

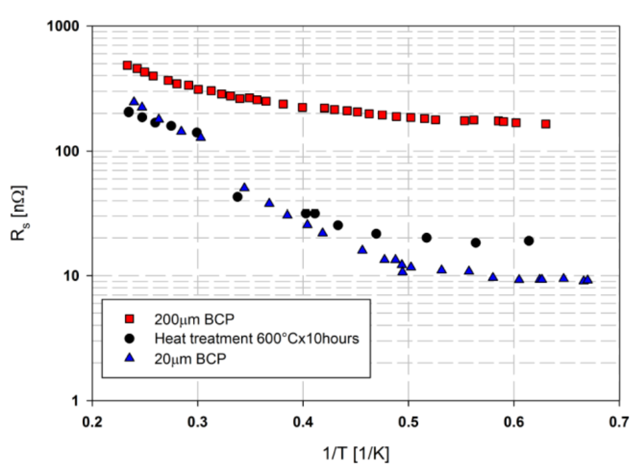

Figure 6: P01 surface resistance with respect to temperature at different preparation phases.

SUMMARY

Six medium beta cavities have been manufactured for the Elliptical Cavities Cryomodule Technology Demonstrator (ECCTD). One cavity has been fully prepared before tank welding and exceeds design requirement during vertical test, a second one has been tested after the first BCP (200µm) showing better performance respect to the predecessor at the same phase. We will be soon be able to test the first cavity integrated with the helium tank. At the same time we are improving the BCP process in order to obtain better performance also without heat treatment.

APPENDIX

Magnetic Field Measure

Recently, a new set-up to measure magnetic field in cavity proximity during vertical tests has been installed. It consists of 3 fluxgate sensors (figure 7) in order to measure all the field components. The vertical cryostat is also equipped with compensation solenoid that allows the minimization of the magnetic field vertical component in the cavity region (average amplitude of 0.1µT), while the radial part is between 1 and 2µT. Recently we start to observe some drifting in the fluxgate measures, and the causes are under investigation.

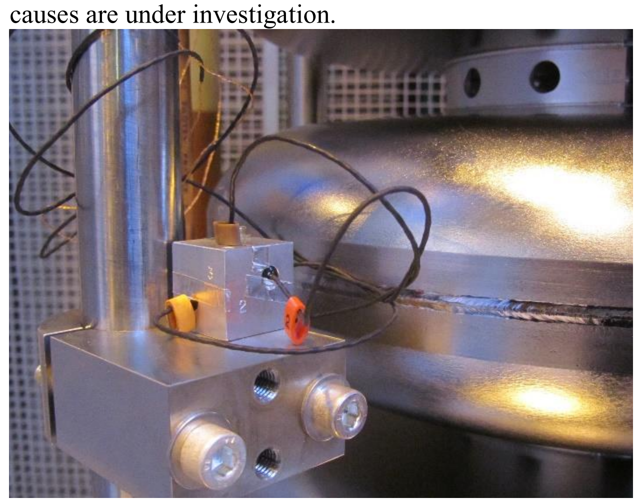

Figure 7: Fluxgate probes installed near the cavity surface in the equator region.

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