700 MHZ SUPERCONDUCTING PROTON CAVITIES DEVELOPMENT AND FIRST TESTS IN THE HORIZONTAL CRYOSTAT "CRYHOLAB"

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Abstract

High intensity proton accelerators based on Superconducting RF Cavities (SCRF) are considered for various applications such as nuclear waste transmutation, radioactive ion beams, neutrons sources or neutrino factories. A collaboration between the CEA-Saclay and the IPN-Orsay groups involved in SCRF activities is working on the 700 MHz elliptical cavities for the high energy part of the linac. The goal is to design, manufacture and test a cryomodule with two beta 0.65 five cells cavities and their associated components (helium tank, cold tuner, coupler...). Monocell cavities have been fabricated and tested to validate the design, and the first five cell cavity (beta = 0.65) fabrication is almost achieved. This paper presents the technological choices for the cavity design, the cavity tests in vertical cryostat and also the first cryogenic tests in the horizontal test stand "CryHoLab" for the installation validation.

1 INTRODUCTION

Superconducting RF Cavities (SCRF) are extensively studied since they are the main component of high intensity proton accelerators, which are considered for several applications: nuclear waste transmutation, radioactive ion beams, neutron sources or neutrino factories. Two European major projects have entered the conceptual design phase and thus drive an important R&D program. The eXperimental Accelerator Driven System (XADS) [1] is a proposal to study and construct a demonstrator (600 MeV, 20 mA, CW) for nuclear waste transmutation. The second project, EURISOL (1 GeV, 5 mA, CW) is a radioactive nuclear beam facility, based on the ISOL (Isotope Separation On Line) technique [2]. Other projects are also based on the same driver accelerator, for example, the European Spallation Source (ESS) and the Superconducting Proton Linac (SPL), the neutrino factory project of CERN.

A collaboration between the CEA-Saclay and the IPN-Orsay groups involved in SCRF activities is working on 700 MHz five-cells elliptical cavities for the high energy part of such a linac. First, we focused on $\beta = 0.65$ cavities. After validation of the cavity geometry by means of RF tests on single-cell prototype cavities, the manufacturing of the first five-cells was ordered at the CERCA company (Fig. 1). Specific tests and controls were made at several stages of the cavity fabrication (half-cells precise geometry control, superfluid helium leak test for the brazings, ...).

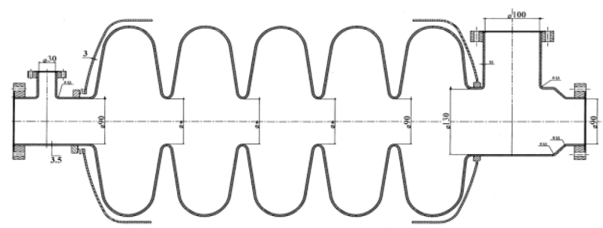

Figure 1: 700 MHz five-cells cavity geometry.

2 SINGLE-CELL PROTOTYPES

2.1 Cavity design and technological choices

A shape optimization based on cavity simulations using RF codes was performed to minimize the ratio B_{pk}/E_{acc} and E_{pk}/E_{acc} [3]. Monocell cavities (Figure. 2) have then been fabricated and tested in order to validate the cavity shape and specific technological choices: a stainless steel helium tank, brazed with a copper alloy onto the niobium beam tubes. This solution should drastically reduce the cavity cost as compared to the classical titanium helium tank.

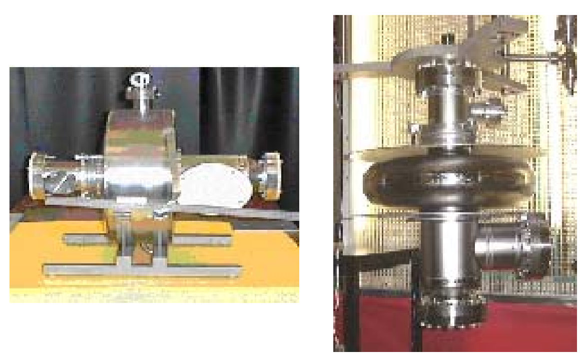

Figure 2: 700 MHz A105 Monocell cavity before (right) and after (left) the helium tank welding.

Two monocell cavities, named A102 and A105, were fabricated using high RRR 200 niobium of 4 mm thickness. The cavity A102 has the shape of the five-cell cavity inner cells. The A105 cavity (Figure 2) is composed of the first and the last half-cell of the five-cells cavity. It has a coupler port (Φ100) and the two stainless steel helium tank flanks.

2.2 Vertical Tests

Both cavities were tested at 1.7 K in a vertical cryostat in the CEA-Saclay laboratory. Both cavities reached high performances far beyond the specifications, with an accelerating field E_{acc} above 25 MV/m and a peak magnetic field B_{pk} above 120 mT. These results are presented on the figure 3.

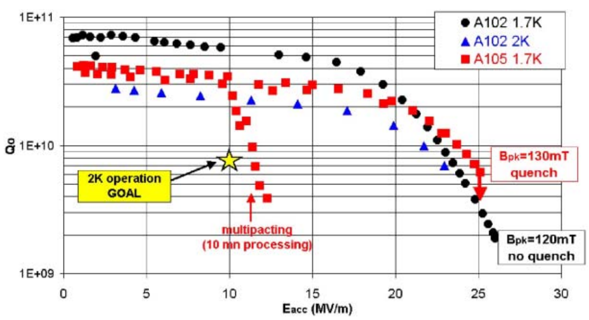

Figure 3: Results of the prototypes A102 and A105 700 MHz, β = 0.65 monocell cavities.

2.3 Horizontal Test in CryHoLab

The A105 cavity was then prepared for its first test in the horizontal test-stand CryHoLab (Figure 4): the stainless steel helium tank was welded at IPN laboratory to the already existing flanks.

The main goal of this test was to validate the CryHolab installation, both from the cryogenic and RF point of view. No good results were expected from the cavity as it was not heat-treated at 800°C and because the cryostat magnetic shielding was only partially achieved. Therefore, the Q_0 was limited to 5 10^8 @ 2K.

Figure 4: A105 cavity in the CryHoLab test stand.

3 FIVE CELLS CAVITY FABRICATION

A β = 0.65 700 MHz 5 cells cavity has been manufactured at the CERCA company. The several technological choices and the fabrication procedures and controls are presented below. The Niobium sheets for the cavity cells, supplied by Wah Chang, have a RRR > 250 and, according to mechanical calculations, a thickness of 4 mm. The beam and pick ups' tubes, 2.8 mm thick, are made of a reactor grade niobium sheets .
The different half-cell profiles and two different extremities [3] are formed by spinning. These different parts are then bounded by Electron Beam welding (EB). Only one weld is made at a time and prior to EB each welded face surface is prepared with a chemical etching small (~30 µm). The EB penetration depth is 2.8 mm for the cut-off cells assemblage at iris, 2.8 mm at equators and 3.6 mm at iris for the central half cells. The Conflat© type (CF) flanges on the coupler ports and the beam tubes are made of 316 LN forged Stainless Steel (SS). These flanges are brazed with a copper alloy on the niobium tube and are machined after brazing to avoid deformations of the knifes which could lead to leaks. In the same idea the helium tank domed end cups, made of 316 L SS are also brazed with copper alloy on the beam tubes. Using SS instead of (Lhe tank, bellows…), reduces the price and increases the stiffness of the Cold Tuner System/ helium tank assembly. The main sequence of the cavity fabrication process (EB, TIG and brazing) are illustrated in Figure 5.

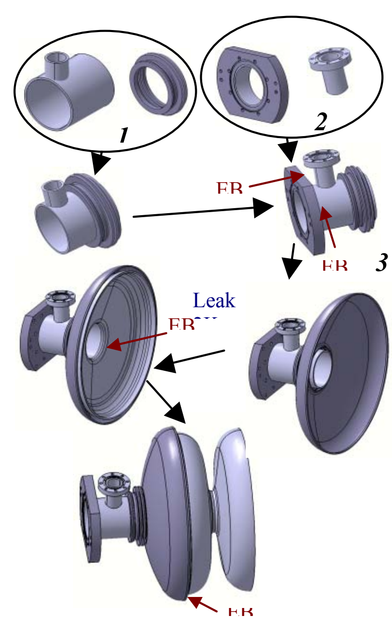

Figure 5 : Cavity fabrication process

All the brazed parts are first individually gathered (2) on Niobium (the bellow ring on the beam tube, the CF flanges on small length tubes …) . As the EB encounters no parts in its trajectory, it is possible to weld all this parts together to make the cut–off assembly (3). Then the helium tank domed end cups are TIG welded (4). At this stage an other domed cup was TIG welded on the helium tank cup to carry out an overall leak detection in superfluid helium in order to validate the tightness of the copper brazing and the Conflat© flanges. These tests showed no leak with a sensitivity of 10^{-9} mbar.l/s.

The extremities half cells are EB welded at the iris on the cut-off from inside the cavity (5). The central half cells are EB welded, by pair, at the iris to form 4 "diabolos". The "diabolos" and the two ends , are then bounded together with external EB welds (6) at the equator.

A geometrical control, with 3D measurements device was made on each of the eight central half cell before the welding. The aim of these measurements is to study the geometrical changes after each manufacturing stages (spinning, welding, Room Temperature (RT) tuning). For each half cell, four internal profiles (i.e 4 azimuthal positions at 90 ° apart from each other) and one external profile were measured with a step of 0.5mm. The reference was given by a virtual axis passing through the measured middles of the iris and the equator diameter .

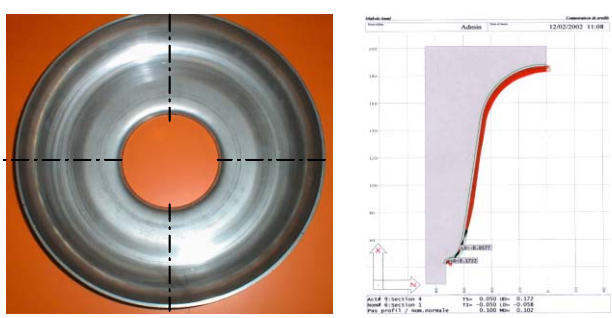

Figure 6 : Half cells profile measurements

The data obtained for the eight half cells are summarized in Table 1.

Table 1 : 3D measurements data on 8 half cells

	Φ equ.	Φ iris	Max Shape dispersion	Thick.
mean	372.76	89.52	+/-0.5mm	3.84
SD*	0.21	0.04		0.08
Design	372.8	90		4 mm

* Standard deviation

In Table 1 the maximum shape dispersion means that any point of the measured profile is included in a range of +/- 0.5 mm around the designed profile.

The whole 5 cells cavity will be re-measured with the 3-D device before and after the Room Temperature tuning. Thus it will be possible to observe any effect of the welding necking and to compare the measured fundamental mode frequency to the RF calculations results obtained with the measured geometry [4] .

4 FUTURE WORK

The mono-cell cavity has been annealed and is to be equipped with piezoelectric actuators to study dynamical effects (microphonics and Lorentz forces detuning) on the cavity A105 with its Lhe tank. Measurements of the RF characteristic after annealing at 800 °C and study of the cavity mechanical behavior @ 2K will be performed in CRYHOLAB at the beginning of July.

The 5 cells cavity will be supplied at the beginning of June. Two 3-D geometrical measurements of the whole structure will be made to analyze the effects of welding and Room Temperature tuning on the cavity geometry. The facility for 5 cells cavity chemical treatments will be achieved in September. Then a first test in a vertical cryostat will be performed before and after annealing at 800 °C (100 K effect). The cold tuning system will be manufactured for October, then a first horizontal test, in CRYHOLAB, of the cavity equipped with its helium tank and its cold tuning system is planned for the beginning of year 2003.

5 ACKNOWLEDGEMENT

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