RF TESTS OF THE BETA=0.5 FIVE CELL TRASCO CAVITIES

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Abstract

Two complete 5 cell superconducting cavities at β=0.5 have been fabricated in the TRASCO INFN program. The cavities have been designed to minimize peak electric and magnetic fields, with a goal of 8.5 MV/m of accelerating gradient, at a Q > 5 10^9. The cavities have been tested in vertical cryostats at TJNAF and Saclay and the results are summarized here.

INTRODUCTION

As part of the TRASCO program multicell superconducting cavities of the elliptical type have been designed, in collaboration with CEA and IN2P3 for the design of an ADS system based on a superconducting linac [1, 2]. In the past years four single cell β=0.5 cavities have been fabricated by the Italian company Zanon and tested in collaboration with TJNAF and Saclay. The results of the RF tests have been very successful and were reported at EPAC 2002 [3]. After these tests, the fabrication of two complete stiffened 5 cell structures was launched.

CAVITY FABRICATION

High RRR (>250) niobium sheets of 4 mm thickness have been used for the cavity fabrication. The parts were formed and electron beam welded at Zanon. The half cells were deep drawn using two set of dies for the equator and iris regions. Two half cells of the internal shape have been welded at the iris to form the dumb bells, and a ring was welded at 70 mm distance from the beam axis, in order to decrease the sensibility to Lorentz forces and increase the cavity stiffness. The dumb bells were then trimmed in length to adjust the frequency. The end tubes (with diameter 130 mm at the power coupler side and 80 mm at the other side) were then formed, equipped with coupler, pickup, HOM ports and flanges on the beam axis and welded to the end cells. Two titanium disks have been welded though NbTi transitions at the cavity beam tubes to provide support for a Ti helium tank, that will be equipped in the future. The dumb bells and the end sections were then mounted in a dedicated fixture for the final equatorial welds. NbTi flanges derived from the DESY and SNS types, using AlMg3 gaskets, have then been used for all the ports. Finally, the pickup and power coupler flanges have been added in the last electron beam welding stage.

The resulting cavity is shown in Figure 1.

During the stages described above, the half cells and dumb bells frequencies have been measured in order to determine the spread due to fabrication (< 1 MHz) and the required amount of trimming for frequency adjustment.

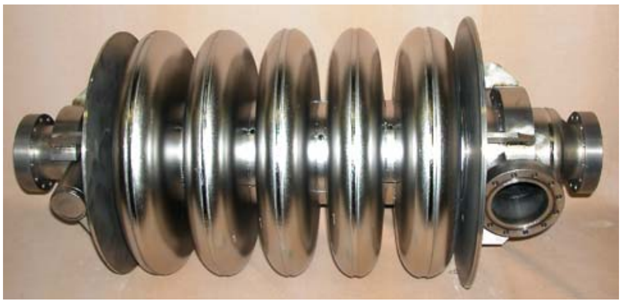

Figure 1: The Z502 cavity.

5 CELL RF TESTS

The main cavity parameters are described elsewhere [1] and are summarized in Table 1.

Table 1: Main 5 cell Cavity Parameters

Parameter	**Value**
Design Frequency	704.4 MHz
Geometrical β	0.47
Iris radius	40 mm
Cell to cell coupling	1.34 %
R/Q	180 Ohm
G	160 Ohm
E_{peak}/E_{acc}	3.57
B_{peak}/E_{acc}	5.88 mT/(MV/m)
Stiffening ring radial position	70 mm
Lorentz Force Coefficient (est.)	-7 Hz/(MV/m)^2

Z501 procedures at TJNAF

The cavity has been sent to TJNAF after fabrication, where it was tuned for a field flatness of 7% at the room temperature frequency of 699.268 MHz. The cavity has then undergone an initial degreasing, a BCP 1:1:2 (HF, HNO_3, H_2PO_4) etching to remove 150 µm, and a thorough rinsing. Then, the cavity was heat treated at 600°C in vacuum for 10h, standard SNS procedure, to desorb hydrogen generated during the chemical treatment and absorbed in the bulk material. A field flatness of 5.5 % at 698.856 MHz was reached in a second tuning stage. A final chemistry with a 100 µm removal was then followed by rinsing and two stages of High Pressure Rinsing. The cavity was then left to dry overnight in the class-10 clean room before the installation of the input antenna in the main coupler port and a second antenna in the pick-up port. One of the main beam pipe ports was used to connect to the vacuum pump, and the other was closed by a stainless steel blank flange. The cavity flanges were closed with the SNS AlMg3 gaskets, derived from TESLA cavities. The cavity was then suspended on the vertical insert, supported at the He-vessel end dishes by a titanium cage. The cavity was evacuated and sealed, no pumping was provided during the RF tests.

Z502 procedures at Saclay

The Z502 cavity has been tuned to 5% field flatness at 700.195 MHz in LASA before sending it to Saclay. Here a total of 120 μm has been removed in two BCP stages from the cavity inner surface, leading to a final frequency (room temperature, in air) of 699.83 MHz. The chemistry was followed by a thorough high pressure rinsing, then the cavity was left to dry overnight in the clean room before the assembly of the antennas at the main coupler and RF pick-up positions.

The cavity beam flanges have been closed with indium joints, while the AlMg3 gaskets were used to seal the main coupler and pickup ports. Finally, the structure has been equipped with a stainless steel frame in order to provide sufficient stiffness. Pumping was provided through one of the beam ports.

Figure 2: The cavity supports at TJNAF (left) and at Saclay (right).

The cavity has not been heat treated for hydrogen desorption, so a rapid cooldown procedure has been followed, to avoid the 100 K, “Q disease”, effect.

A small leak developed after the superfluid transition was reached, and it was necessary to pump the cavity with a turbomolecular pump during the RF tests in order to maintain good vacuum conditions (< 10^{-6} mbar).

Results of the RF tests

The surface resistance as a function of the inverse of the temperature during the cooldown is plotted in Figure 3 for the two measurements. The experimental data have been fitted with the BCS theory (using Halbritter’s code [4]) in order to obtain an estimation of the residual resistance. A value of ~ 5.5 nΩ in the TJNAF tests and 7.0 nΩ for the Saclay measurements has been obtained, typical of the high RRR niobium material used.

During both tests two multipacting barriers have been observed. The first one appeared at low field values (ranging from 1.5 to 3 MV/m) and was easily overcome. In the second barrier (ranging from 6 to 8 MV/m) there were signs of strong electron emission, that lead to continuous cavity quenches when the cavity approached the barrier level, due to the induced local heating. This multipacting level was anyhow processed with approximately half an hour of RF processing on the fundamental and in the other modes of the band. After this procedure, no further signs of multipacting were observed during further testing.

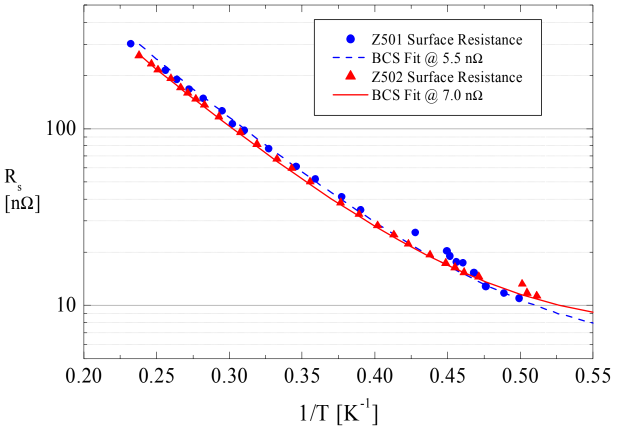

Figure 3: R_s values from RF measurements.

The curve of the cavity quality factor, Q_0, as a function of the accelerating field is shown in Figure 4 for the two tests of Z501 (TJNAF) and Z502 (Saclay). Both cavities outperformed the design accelerating field value of 8.5 MV/m.

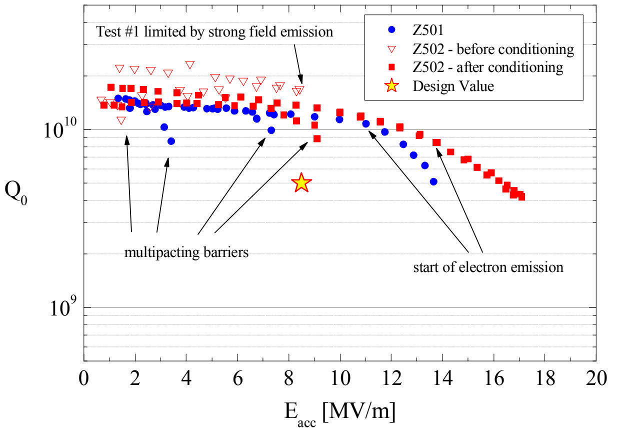

Figure 4: Q vs E_{acc} curve for the two cavities.

In the TJNAF Z501 tests the two multipacting barriers were encountered at 2.8 and 6.8 MV/m. The first one was processed quickly, while the second took 20 minutes of RF processing in the 4/5 π more. The cavity was limited by field emission at higher fields (starting from 11 MV/m) and reached an accelerating gradient of 13.7 MV/m with a quality factor, Q_0, of 5 10^9.

In the tests at TJNAF the Z501 cavity showed a higher than expected frequency sensitivity to the accelerating field. A static Lorentz force coefficient of nearly 47 Hz/(MV/m)^2, close to the case of “free” boundary conditions, was determined from the RF tests, indicating that the cavity was weakly constrained in length during the tests. Further tests with a stiffer cavity length constraint are planned in TJNAF.

The two barriers encountered during the Z502 Saclay tests were at approximately 1.5 and 8 MV/m. Like in the TJNAF test the former barrier was processed quickly, while the second needed more than 30 minutes of RF processing in the 2/5 π and 4/5 π modes of the cavity band. During the conditioning process the cavity quenched continuously when approaching the barrier level, due to the local thermal heating induced by the strong electron emission hitting the surface. After the conditioning, the barriers were not experienced in successive tests.

Also in this case the Z502 cavity was limited by field emission (starting at 13 MV/m), and reached the value of 17.1 MV/m with a Q_0 of 4 10^9.

A static Lorentz force coefficient in the range from 20 to 35 Hz/(MV/m)^2 has been determined from the Saclay RF measurements. Figure 5 summarizes the static Lorentz coefficient estimated from all the measurements. Three data sets were taken from the Z502 cavity and a single data set for Z501. The data at low and high fields has not been used for the K_L estimation, due to the limited accuracy in the measurement frequency at low fields and the electron emission occurring at high fields. The spread in the resulting K_L value seems compatible with the support frames used in the experimental setup, based on 3 or 4 thin rods that provide some mechanical constraint on the cavity length. The estimation of 7 Hz/(MV/m)^2 is indeed based on a mechanical model for a constrained (fixed length) internal cell geometry [1] and rises up to nearly 90 Hz/(MV/m)^2 for the case of an unconstrained cell length. Therefore, the detailed interpretation of the experimental data requires a more detailed analysis of the full cell geometry coupled electromagnetic/mechanical calculations and further dedicated tests.

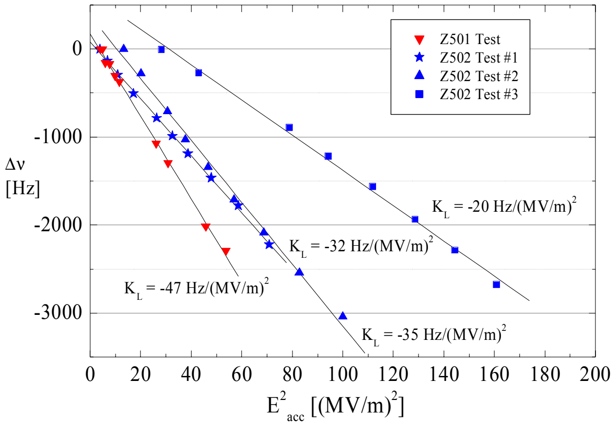

Figure 5: Lorentz force coefficient estimations from RF measurements.

CONCLUSIONS

Both the TRASCO cavities outreached the nominal specifications with a considerable operational margin. The corresponding peak electric and magnetic fields reached in the TJNAF tests are 49 MV/m and 81 mT, yielding compatible performances with the ones achieved by the multicell SNS cavities. The tests at Saclay reached peak electric and magnetic fields of 61 MV/m and 100 mT, respectively, with performances similar to the standard TTF cavities production. In both tests the cavity performance was limited by field emission at high fields, and considering the peak electric field on the surface, the performance limits were compatible with a BCP treated TESLA cavity shape in the 25-30 MV/m range. This limitation suggests the possibility to treat the cavity with further BCP and longer HPR procedures in order to possibly suppress electron emitters and reach the thermal quench limit at even higher fields.

The cavities will be in future equipped with a helium vessel for measurements in the horizontal cryostat “CryHoLab” at Saclay, after heat treatment and the welding of the Ti helium tank. Finally, the cavities will be equipped with a prototype of a cold tuning system, derived from the coaxial blade-tuner proposed for the TESLA cavities [5], integrated with a piezoelectric fast tuner system in order to assess its behaviour under pulsed operation at the design fields.

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