FREQUENCY MEASUREMENT OF 1.3 GHz SINGLE CELL CAVITY DURING COOL DOWN UPTO 77 K

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Abstract

RRCAT Indore has initiated a program for the development of 1.3GHz, Superconducting RF (SCRF) Cavities & establishing the required infrastructure. The SCRF cavities are operated at low temperature (2K). A computer controlled setup has been developed to test the SCRF cavities at low temperature for variation in frequency. To study the thermal contraction effect on RF resonating frequency of the cavity and also to qualify the cavity EB welded joints for low temperature operation for vacuum leak tightness better than $1x10E^{-9}$ mbar.l/s, a setup was developed to cool the RF cavity from room temperature to 77K and monitor the vacuum and resonant frequency. RTDs are used to measure the temperature of the cavity. The resonant RF frequency is measured using a Vector Network Analyser. The paper presents the results of measurement of resonant frequency and comparison with theoretical drift in resonating frequency during the cool down of single cell cavity.

INTRODUCTION

Most of the bulk Niobium superconducting radiofrequency cavities are operated at 2K. The cavities undergo thermal contraction during cool down from room temperature to 2K, which increases the resonating frequency of the cavity. Therefore the study of shift in the cavity resonant frequency during cool down is important. Moreover, it is required that the welding joints shall be tested after giving thermal shock up to liquid nitrogen temperature to ensure the vacuum leak tightness.

The system developed at RRCAT has been used to qualify niobium cavities for measuring the frequency shift and vacuum leak tightness at 77K. The experimental value obtained on Niobium cavities has been compared to the theoretical drift in resonating frequency calculated using ANSYS simulation. Some of the prototype cavities fabricated in copper were also tested.

CAVITY COOL DOWN ANALYSIS

The ANSYS Thermal-structural-electromagnetic coupled finite element Analysis for the cavity has been carried out to evaluate the effect of LN_2 cooling on cavity frequency. The cavity is cooled down from room temperature to 77K and the thermal structural coupled analysis has been carried out to evaluate the deformations in the cavity. Fig1 shows the deformation pattern. The high frequency electromagnetic analysis for the deformed cavity has been performed to evaluate associated

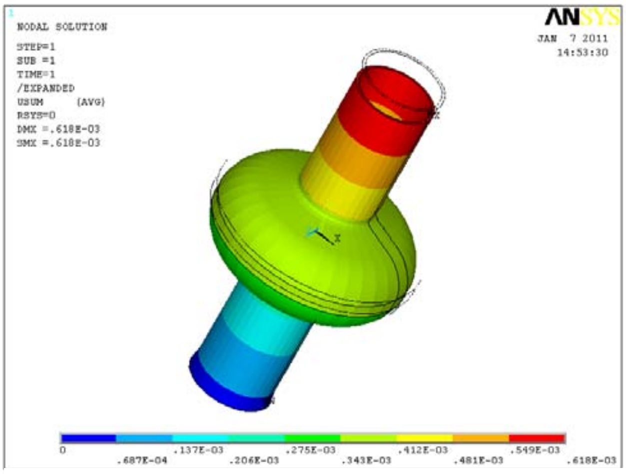

Fig.1: Deformation Pattern for 1.3GHz Niobium Single Cell Cavity. The Maximum Deformation in the Cavity is 0.618mm.

frequency shift resulting from he cool down. For the change in temperature from 300K to 77K the change in resonant frequency of single cell Niobium cavity is found to be 2.1 MHz.

Measurement Setup

The tasks involved in measurement setup were

1. Evacuating the single cell SCRF cavity
2. Leak detection and measurement of pressure
3. Measurement of resonant frequency
4. Measurement of temperature at various locations
5. Cooling down the cavity to 77K
6. Data Acquisition and analysis

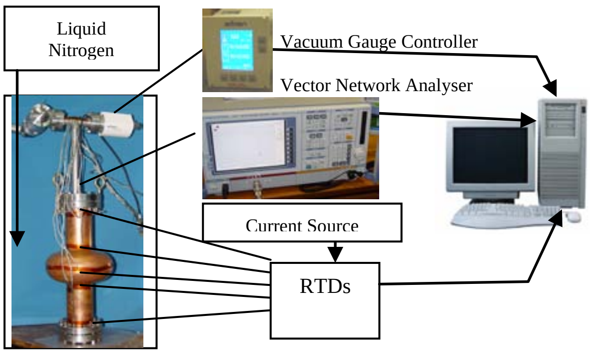

Fig.2: Schematic of Setup for Frequency Measurement of 1.3 GHz Single Cell Cavity during Cool down from Room Temperature upto 77 K

The cavity was sealed by two end flanges at the ends. Indium wire seal was used for vacuum sealing. One of the end flanges was fitted with KF25 port to evacuate cavity and a RF probe was used to feed low power RF stimulus. The welded joints of cavity were tested for leak tightness for leak rate less than 1E-10 mbar.l/s using a He leak detector. A Turbomolecular pump was used to evacuate the cavity to 1E -5 mbar. A combination gauge (Pirani and cold cathode) is used to measure the vacuum. Pressure data is transfer to Computer (PC) using RS232 serial communication.

A vector network analyser (VNA), R&S ZVB4 was used to measure the resonant frequency of the cavity. A 100mm antenna was used to feed RF. A special feed through was fabricated to feed RF stimulus while maintaining the vacuum compatibility even at low temperature. The data from VNA was transferred to PC through GPIB interface.

Temperature of the cavity at pipe, iris and equator were measured using RTDs (Pt 100). The PTFE insulated wires were shielded to reduce the noise. A Data acquisition card was used to acquire temperature data on PC.

A program was written in LabVIEW to process the data. The cavity was positioned vertically inside the tank. The tank was slowly filled with liquid nitrogen to cool the cavity. The data for frequency, temperature and vacuum were acquired on a PC for further analysis. The schematic of the setup is shown in Fig 2.

RESULT

The cavity was found to be leak tight for a leak rate less than 1E-10mbar.l/s at room temperature as well as at low temperature. The variation in the frequency from 300K to 77K was found to be 1.8 MHz and 4.05MHz for of Niobium and Copper single cell

Table1: Variation of Measured Frequency With Temperature

	Theoretically Calculated values		Measured Values	
Single cell Cavity	Temperature (K)	Frequency (MHz)	Average Temperature (K)	Frequency (MHz)
Copper	300	1300.967	298.0	1294.861
	250	1302.004	250.2	1295.562
	200	1303.086	200.3	1296.313
	150	1304.171	150.0	1296.788
	100	1305.257	100.2	1298.603
	77	1305.757	77.2	1298.916
Niobium	300	1300.967	299.8	1297.200
	250	1301.400	248.6	1297.733
	200	1301.890	203.6	1297.867
	150	1302.374	150.7	1298.467
	100	1302.850	104.5	1298.967
	77	1303.069	77.5	1299.005

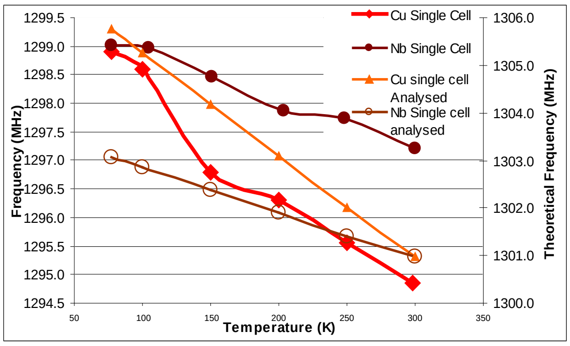

Fig.3: Temperature vs Frequency Variation of 1.3 GHz Single Cell Cavities during Cool down from Room Temperature upto 77 K

respectively. Table 1 and fig 3, shows the variation of frequency and temperature.

CONCLUSION

The frequency shift during the cool down has been calculated using FEM and also experimentally measured. The measured values for frequency differ slightly from the computed values. This may be attributed to the fact that, during computation the cavity is assumed to be at constant temperature, while during cool down experiment a temperature gradient exists in the cavity. The variation in the cavity frequency is due to the difference in calculated and fabricated cavity shape. Also the various cavity fabrication processes such as forming, trim machining and welding deviate the cavity shape from ideal one. However, the change in frequency will be restored to its designed resonating frequency by stretching or compressing the cavity with the help of cavity tuning fixtures. A setup is developed to test the welding joints of the cavity at low temperature. This will help to qualify the superconducting cavities for further processing. The experience gained will be useful in design and fabrication of 9 cell cavity.

ACKNOWLEDGEMENTS

We acknowledge Dr P.D. Gupta, Director, RRCAT, Indore, for his kind support & guidance in SCRF Cavity developmental activity. We thank Cryo-engineering and Cryo-module Development Section, RRCAT for providing Liquid Nitrogen. We Thank Glass Blowing Facility section, for their help in fabrication of RF connector. We also acknowledge the support given by the staff of PLSCD, RRCAT, for help extended in developing the setup.