A.4: Design, simulation and installation of the power and the pickup couplers for 5-cell, β=0.92 SCRF cavity

Superconducting radio frequency (SCRF) cavities are being used in particle accelerators which require high gradient along with long pulse and CW operation. Before installation in accelerators these cavities need to be tested for the maximum accelerating electric field gradient (E_{acc}) and intrinsic quality factor (Q_0). Bare SCRF cavities are RF qualified first at Vertical Test Stand. This RF testing is done with near critical coupling so as to minimize RF power requirements. As the electric field gradient increases in the cavity, its quality factor decreases due to surface current heating. In order to ensure maximum power is transmitted to cavity while operating at maximum design gradient, the Fundamental Power Coupler (FPC) is commonly designed to be over coupled at low gradients and be close to critically coupled at maximum gradients. A second coupler or pick up probe (FP) is also used to measure E_{acc} generated inside cavity. This coupler is kept under coupled with quality factor of FP (Q_{FP}) being around 100 times higher than that of cavity so as to avoid loss of power. The pickup coupler samples the transmitted power, which is used to calculate accelerating electric field and quality factor.

For qualification of first β=0.92, 5-cell Nb SCRF cavity developed by RRCAT, the design and simulation was done for both the FPC and the field probe by PHPMD, RRCAT. The simulations were done using CST Microwave Studio. The design goal was to keep Q_{FPC}~8E9 and Q_{FP} ~2E12. The quality factor for a good cavity was expected to be close to 2E10 at high E_{acc}. The Q_{FPC} was intentionally kept lower so as to allow better RF processing.

The couplers were designed for π mode frequency. Field distribution in 5 cell cavity in this mode is shown in Figure A.4.1. After design and simulation the couplers were fabricated and the actual quality factor of these couplers was calculated at room temperature using a VNA. A special procedure was followed to accurately measure the quality factor as at room temperature the signals from cavity are extremely weak.

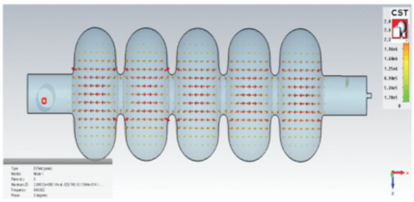

Fig. A.4.1: Electric field profile of 5cell SCRF cavity.

For a given thickness of the coupler its quality factor depends upon its length. Simulations were carried out to identify the length vs quality factor for both FPC and FP. The couplers were fabricated with longer length than the design value and based on room temperature measurement the length was reduced in steps to arrive at the optimum. Figure A.4.2 and A.4.3 present the length vs quality factor variation of the FPC and the FP respectively.

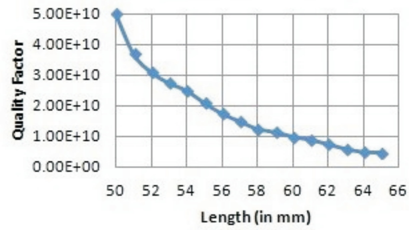

Fig. A.4.2: Quality factor variation of FPC with respect to its length(mm).

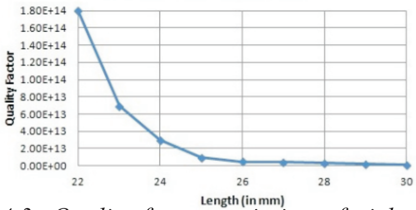

Fig. A.4.3: Quality factor variation of pick up probe with respect to its length (mm).

The couplers, as optimized with room temperature measurements, were installed with the cavity and used during cold tests. The coupler values were recalculated during VTS test which have been found to be fairly consistent with the simulation and room temperature measurements. The simulated and measured values are tabulated in Table. A.4.1. Figure A.4.4 shows room temperature measurement being carried out on 5-cell cavity.

Table A.4.1: Coupler's quality factor simulated and measured value.

Coupler	Power coupler	Pick up coupler
Simulated value	8.2E+9	2.21E+12
Measured value @ 300K	7.89E+9	2.2E+12
Measured value @ 2K	7.78E+9	2.18E+12

Fig. A.4.4: Coupler's quality factor measurement at room temperature.

Reported by:
Kunver Adarsh P. Singh (adarshsingh@rrcat.gov.in) & colleagues