UPDATE ON COAXIAL COUPLING SCHEME FOR ILC-TYPE CAVITIES*

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Abstract

We have in the past reported about our efforts to develop a flangeable coaxial coupler for both HOM and fundamental coupling for 9-cell ILC-type cavities. The design of the coupler was done in a way, that the rf magnetic fields at the flange connection were minimized and only a field of <5 mT would be present for a magnetic field of 160 mT (Eacc ~ 35 MV/m) in the cavity. Even though we achieved reasonably high Q-values at low field, the cavity/coupler combination was limited to only ~ 7 MV/m accelerating electric field in the cavity, where a thermally initiated degradation occurred.

We believed that this limitation was caused by poor cooling of the shorting plate and inner tube in the coaxial coupler; therefore, we have improved the cooling conditions by drilling radial cooling channels into the shorting plate. This paper reports about our experiences with the modified conditions.

INTRODUCTION

In the coaxial coupling (CC) scheme, shown in Fig. 1, all couplers are shielded by the inner tube, which is supported by the Nb disk welded to it and to the beam tube. The disk is an electric short in the coaxial line, which is formed by the inner and outer tubes, and thus separates electrically two mirrored coupling devices and neighboring cavities. The pair of mirrored coupling devices can be flanged between two cavities. The flanges are located ~35 mm apart from the end irises, at the positions where the standing wave of the magnetic field has its notch. The coaxial HOM couplers were originally developed for the 500 MHz HERA cavities in 1985 and later in the early 90's they were scaled to 1300 MHz and adapted for the TESLA cavities [1]. The scheme fulfills also the specification for the ILC project, which is the TESLA successor, and can be used for the superconducting cavities in the main accelerator.

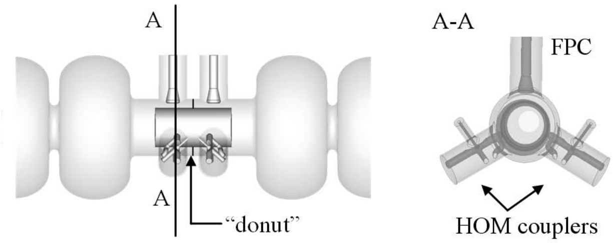

Figure 1: FPC and HOM couplers in two mirrored coaxial coupling devices placed between two cavities (left) and cross-section of the coupling device (right).

Our motivation to develop the CC scheme has been discussed comprehensively in [1]. Here, we recall some arguments. The CC scheme has the following advantages as compares to the standard TESLA scheme:

- Field asymmetries and kicks from all couplers are small.
- The distance between two cavities is shorter.
- The body of the cavity stays cylindrically symmetric, which enables its fabrication by hydro-forming as a seamless device.
- The interior of the coupling device and the cavities can be better cleaned before the final assembly.
- The CC scheme provides for good damping of HOMs and for easy matching of the fundamental mode coupler.

PREPARATION FOR TESTING

The Nb prototype of the CC device was built at TJNAF in 2008. The prototype is simplified compared to Fig. 1 because it is equipped with only two HOM couplers and has no input coupler port.

We chose a 1.6-cell SRF gun cavity, built in the frame of another superconducting R&D project, for the cold tests of the CC device. The cavity and CC device are shown in Fig. 2.

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Figure 2: 1.6-cell SRF gun cavity and coaxial coupling device before the assembly.

Both the CC device and cavity has electron beam welded conflat flanges, made of the NbZr alloy, for the superconducting connection. The cavity itself is made of large grain RRR niobium. We chose NbZr as flange material because of its good mechanical stability and its better superconducting properties in comparison to Nb55Ti as experimentally verified in ref [2]. However, the mechanical properties of the material we used for the CF flanges turned out to be too soft and the CF knife edge deformed when used with an annealed niobium gasket. Therefore, after each assembly the knife edge had to be "re-sharpened"; this procedure seemed to work reasonably well, since the niobium gasket is also the vacuum seal, which worked fine. On the other hand, as can be seen below, we experienced some variation in the low power Q-value, which we tend to attribute to variations in the knife edge/niobium gasket topography, resulting in a more or less lossy contact. Fig. 3 shows a close-up picture of the NbZr conflat flange and the niobium gasket after disassembly.

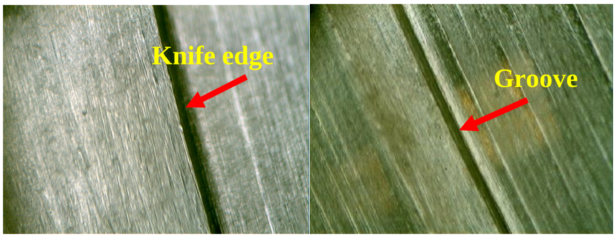

Figure 3: Close-up pictures of NbZr knife edge and niobium gasket groove. Both surfaces are less than ideal.

CRYOGENIC TESTS

Here we report only about tests subsequent to the one's reported in ref. 3.

We have carried out three additional experiments since PAC 2009; all 3 employed single crystal, annealed niobium gaskets. For tests #2 and #3 cooling channels had been drilled radially into the shorting plate between inner and outer conductor as can be seen in Figure 4, whereas, test #1 was carried out without cooling channels.

Figure 4: Modified coaxial coupler assembly with cooling channels; in test #2 channels were drilled every 30 degrees, in test #3 every 15 degrees.

Prior to each assembly, the knife edges on the cavity and the coaxial coupler assembly were mechanically "touched up" with a polishing stone usually used for deburring of lathe cutting tools. Both the conflat flanges and the mechanically polished niobium gaskets received a slight buffered chemical polishing treatment prior to assembly. Cavity and coaxial coupler were high pressure rinse and subsequently dried in our class 10 clean room prior to assembly.

The test results are summarized in Figure 5, indicating that the cooling of the inner conductor is a problem in the original design and could be improved marginally by drilling radial cooling channels into the shorting plate between inner and outer conductor:

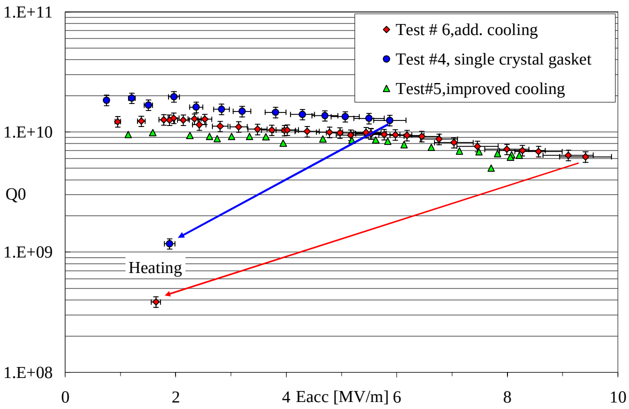

Figure 5: Results from tests with single crystal gaskets and improved cooling.

In all tests we encountered some multipacting (MP) at low fields, which could be overcome by RF processing. The most severe MP occurred in test #2 and it took several hours to pass through the MP level. However, after disassembly of the cavity we found some residue from masking tape; this contamination was accidentally overlooked during cavity preparation and assembly. Usually the MP processed in less than 30 min.

SUMMARY AND OUTLOOK

Even though the concept of a flange-on connection of a coaxial coupling assembly onto a multi-cell cavity is rather straightforward and computer modeling as well as room temperature developments and tests provided excellent agreements, the practical implementation into a superconducting niobium assembly is not as easy.

Our present experience/design confronted us with two problems:

- The edges of the NbZr flanges are strongly deformed after each assembly and the material hardness of the material we used was below the expected value reported by the vendor. We subsequently learnt from the material supplier that the mechanical strength of the material strongly depends on the annealing conditions during material casting and rolling and can be improved.
- The original design of the coaxial coupler components did not provide sufficient cooling to the shorting plate between inner and outer conductors. Some improvements were achieved with radial cooling channels, but these are not sufficient for the cw operation at high gradients.

The way forward to better performance of the assembly will be a replacement of the present NbZr flanges with material of higher hardness, which will better withstand the pressures applied during the assembly with the gasket. If no deformation occurs, a re-work with a grinding stone as mentioned above would not be necessary and it should be possible to achieve a much better surface finish (see Fig. 3) on the knife edges during initial careful machining – this also applies to the Nb gaskets. In this case we expect a better reproducibility of the high Q-values- we attribute the present variation in Q-value to variations in the surface finish of knife edges and gaskets.

The second modification needs to be an improvement of the shorting plate cooling, possibly by removing the “bridges” between the cooling channels and further thinning of the material. Additionally we might be able to construct the inner conductor as a double wall tube for better cooling.

We plan to implement these modifications in the near future.

ACKNOWLEDGMENT

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REFERENCES

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