Coupler conditioning and high power testing of ADS Spoke cavity

CHEN Xu(陈旭)[1;2] MENG Fan-Bo(孟繁博)[1;2] MA Qiang(马强)[2]
HUANG Tong-Ming(黄彤明)[2] LIN Hai-Ying(林海英)[2] PAN Wei-Min(潘卫民)[2]
[1] University of Chinese Academy of Sciences, Beijing 100049, China
[2] Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, China

Abstract: Power couplers, used in China-ADS proton linac injector I, are required to transfer 6 kW RF power to the superconducting Spoke cavities. At present, first the two couplers of a coaxial design have been fabricated, which accomplished a high power test at IHEP. The test results indicated that couplers of this design are qualified to deliver 10 kW RF power in continuous travelling wave mode. This paper describes the coupler's room temperature test procedures and results and discusses the original high power test, which was terminated due to serious out-gassing and after some modifications. In the final test, the couplers smoothly exceeded the design power level.

Key words: coupler high power test, Spoke cavities, room temperature

PACS: 29.20.db **DOI:** 10.1088/1674-1137/38/2/027001

1 Introduction

An RF coupler is one of the key components in a superconducting (SC) proton linac. The oupler is a guarantee of impedance matching between the RF source and the load; its primary function is transmitting power from the RF source to the beam loaded cavity efficiently. The coupler also provides a vacuum barrier and holds a temperature gradient to the SC cavity. Its power handling capability and operation stability have to be tested prior to attachment to the cryomodule. Two sets of coaxial couplers with a planar ceramic window have been manufactured and accomplished processing and high power testing at room temperature in late January. This type of coupler will be applied in the China Accelerator Driven Sub-critical System (ADS) proton linac for β=0.12 SC Spoke cavities, which are required to withstand 6 kW of continuous wave (CW) radio frequency (RF) power. Main parameters of this coupler are summarized in Table 1.

2 Test stand

Two opposing couplers were attached to a test stand that allowed baking and following conditioning of both couplers simultaneously. The test stand was custom-designed, which aimed to test the power transferring capability of the coupler [1]. A vacuum was formed between the two warm windows and pumped by an ion pump of 200 L/s, in addition to an aspirator pump of 400 L/s. The test stand was supplied with up to 10 kW RF power from a solid-state amplifier. The two couplers and the connecting test stand were matched to maximize the transmission RF power. The power was transferred from the upstream coupler (1#) to the downstream coupler (2#) via the test stand and terminated with a matched water load at the end. A picture of the block diagram for the coupler test is shown in Fig. 1. The inner conductor and inner window frame shared common water cooling while the outer conductor was cooled by static air. Three monitoring

Table 1. Main parameters of Spoke cavity couplers.

frequency	325 MHz
type	coaxial, antenna E-coupling
window	single, warm, coaxial disk
coupling	fixed
Q_{ext}	7.1E5
input power	Max. 6 kW
impedance	50 Ω

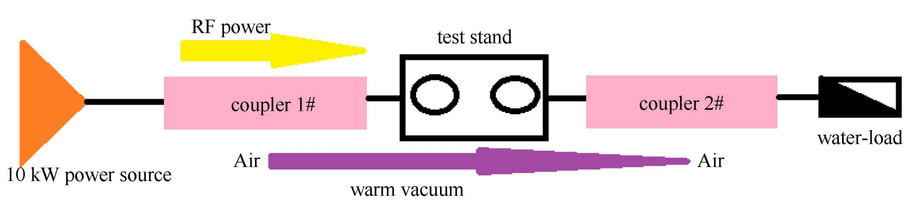

Fig. 1. Block diagram for coupler test.

Received 15 April 2013

ports were set close to the window including a vacuum gauge, an arc discharge and an electron current monitor. These monitoring instruments are very important to prevent a fatal discharge breakdown of the ceramic windows [2]. One of the above signals exceeding the preset threshold will cause a fast cut off of power. Another vacuum gauge was placed at the side-wall of the test stand.

3 Baking

Prior to assembly, all coupler components and other associated parts were cleaned following our procedure to assure ultra cleanness [3]. Couplers were stored in special container for protection from oxidizing and transferred to the test stand, which were handled with non-linty rubber gloves only. For baking, the areas contained windows, outer conductors, test stand wall, ion pump and aspirator pump using three insulated tape heating elements. Several pt100$_s$ were applied to the above areas to measure temperature changes. The baking temperature was controlled by a transformer below 115 ℃, out of concern for the melting point of indium wire. We baked the system under a vacuum for about three days, obtaining a final vacuum pressure of 1.1×10^{-5} Pa; the helium leak of the system was better than 9.5×10^{-10} mbarl/s. The baking process is illustrated in Fig. 2

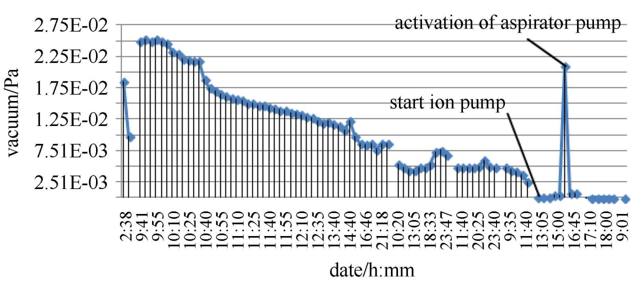

Fig. 2. Record of baking process.

4 Conditioning and high power test

4.1 The final test and observed phenomenon

Conditioning with high RF power before attaching the assembly to the clean cavity is important [4]. A photo of the power test site is shown in Fig. 3. At low RF power, we adjusted the two short circuits of our couplers to minimize reflected power in the transmission line. The voltage standing wave ratio (VSWR) value was adjusted to 1.15 at 325 MHz, which indicated that less than 0.5% of the input power was reflected. This showed a good agreement with the previous simulation of $S11=-49$ dB.

While increasing the RF power in short steps, the fast interlock system runs, which will immediately cut off the RF power if the vacuum bursts or arc events occurr. Only conditioning with a continuous wave method was adopted. It took about 8 hrs of RF conditioning without major arc actions in the coupler to reach 10 kW. The history of the high power test is shown in Fig. 4. No serious vacuum bursts or discharging was encountered. However, most of the interlock events occurred below 2.5 kW and above 8.2 kW. Between 2.5 and 8.2 kW there were very few events and the conditioning time was less than three hours (see Fig. 5). The temperature around the ceramic windows ranged from 31.1 to 31.9 ℃ at the power of 10 kW. Fig. 6 presents a plot of the RF power and the temperature during the test.

Fig. 3. Photo of the test site.

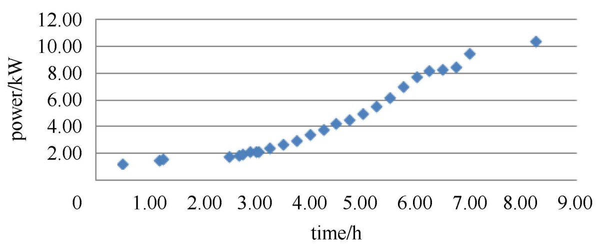

Fig. 4. History of high power test.

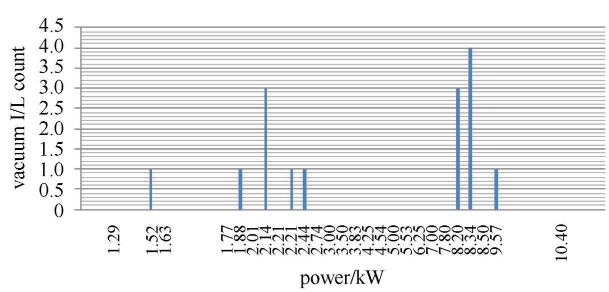

Fig. 5. Number of vacuum interlocks.

In the process of testing, we observed an unexpected temperature difference between the two outer conductors, one had a temperature of 6–10 ℃ higher than the other (see Fig. 6). After exchanging one with the other, the same result as before occurred. We suppose it is the inner coating surface that may lead to this phenomenon.

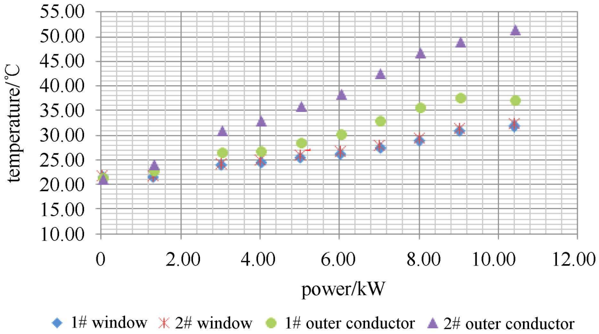

Fig. 6. Temperature as a function of RF heating.

4.2 Comparison with the original test

In our original test, however, the couplers showed excessive out-gassing in some points, which led to several bad vacuum bursts and ion pump breakdown. Recovery of the vacuum pressure was very difficult and time-consuming. Pulsed power conditioning did not help. Therefore, the strong vacuum burst forced us to terminate at 3.8 kW.

We opened the test stand and remade the suspicious part where the (TIG) welding joints of the stainless steel parts seemed to cause out-gassing. TIG welding points may form microscopic pores inside, which were hardly to be detected in the helium leak check and possibly led to the bad vacuum in power test. Furthermore, we reassembled the two couplers and baked them for a longer time, for about three days, with a higher temperature than before. Extending the baking time as well as raising baking temperature improved the efficiency of gas desorption and helped to shorten the processing time. With a series of checking and modifications, in our final RF test mentioned above, a maximum RF power was reached smoothly.

5 Summary

Our first two couplers have successfully passed RF levels of 10kW in excess of the design specifications. The ultimate power is limited by the klystron available. The original test revealed weak points of the fabrication, which has been improved in the final test. The test stand works well after some changes but the possible reasons related to out-gassing need to be better investigated. The long time high temperature baking was effective in desorbing gas and accelerating the processing test. Besides, the TIG welding point properties related with the vacuum must be controlled to avoid pits and unevenness. Temperature differences between the two outer conductors need to be well understood. In future testing of other couplers, we hope to gain a better understanding of the processing limitations.

References

1 Rusnak B, WANG F et al. High Power Coupler Componet Test Stand Status and Results. Proceedings of PAC07. AIbuquerque, New Mexico, USA

2 PAN Wei-Min, HUANG Tong-Ming, MA Qiang. High Power Conditioning of the Input Coupler for BEPCⅡ Superconducting Cavity. Chinese Physics C (HEP & NP), 2008, **32**(9): 766–767

3 HUANG Tong-Ming. Study of High Power Input Coupler for Superconducting Cavity (Ph. D. Thesis). Beijing: Institute of High Energy Physics, CAS, 2009, 88–89

4 Hasan Padamsee, Jens Knobloch, Tom Hays. RF Superconductivity for Accelerator. New York: John Wiley & Sons, INC, 1998. 418–419