ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-WEPRO014

THE INSTALLATIONS OF THE IN-VACUUM KICKER SYSTEM OF THE BOOSTER INJECTION SECTION IN TPS

Chih-Sheng Chen#, Chih-Sheng Yang, Keng-Hao Hsu, Ying-Tzu Huang, Che-Kai Chan, Yung-Hui Liu,
NSRRC, 101Hsin-Ann Road, Hsinchu Science Park, Hsinchu 30076, Taiwan.

Abstract

The installations of the In-Vacuum kicker system of the booster injection in the TPS (Taiwan Photon Source) are presented in this article. Due to the more than 20 kV operating voltage and precise positioning requirements, the insulations and positioning systems are designed with more attentions. Although increasing the gap between high voltage potential parts and ground could provide enough endurance when high voltage is applied, on the other hand, the limited space and vacuum requirements limit the sizes of insulators as well as the chamber. Therefore, lots of efforts have been done to deal with these conflicts. All assembling processes and test results will be described in this paper step by step to reduce the chance of system failure.

INTRODUCTION

Unlike the TLS (Taiwan Light Source), the booster injection kicker system in the TPS is designed as in-vacuum type. It is composed of vacuum system, kicker magnet, alignment structures, supports and insulators basically.

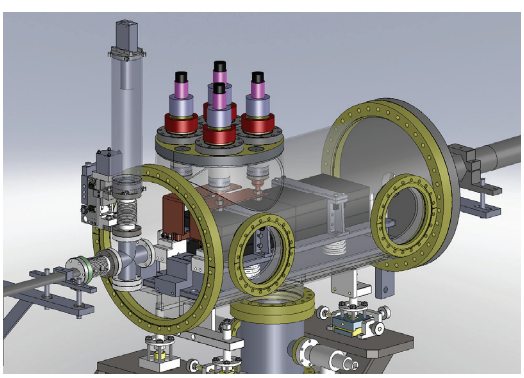

Figure 1:The booster injection kicker system in TPS.

Figure 1 illustrated the drawing of the booster injection kicker system. All magnet components are aligned well and assembled firmly inside the vacuum chamber. Some fixtures are used to enhance the precision of position during assembling, and removed after all components are fixed. In order to isolate the high operating voltage, the ceramic columns and blocks are designed with proper dimensions which provide sufficient insulation and the least space requirement. As for the conducing coil, the oxide free copper is used as the coil material, and with R2 round edges throughout all coil. The curvature of coil bend is R5. In addition, the L-shaped OFC buses connect the coil and the vacuum feedthroughs. These conduction parts will contribute to the inductance of magnet system. Therefore, the arrangement of the copper components is very critical to the performance of the kicker. The ferrite is made of CMD5005 which used in high vacuum environment. Between the coil and the ferrite is 10 mm space and there are 12 pieces of ceramic blocks stuffed within it. The ceramic stuff provides support and insulation. After well assembling, the magnet components are placed into a 350 CF vacuum chamber. Two inlet and two outlet feedthroughs are fixed on the vacuum chamber. The RG-220 cable with 50 ohm impedance is used to connect the pulse power and the kicker.

Table 1:The Booster Kicker Specifications in TPS

Specifications	Booster kicker	
	Injection	Extraction (2 pieces)
Electron energy (GeV)	0.15	3
Bend angel (mrad)	16 [30]	1.3 [2.0]
Beam aperture (mm)	35*20	35*18
Length (m)	0.5	0.5*2
Nominal field (T)	0.016 [0.03]	0.026 [0.04]
Mag. aperture (mm)	65*20	65*18
Nominal current (A)	267 [501]	372 [573]
Pulse shape	Flat top	Flat top
Fall time (ns) 95%-5%	<350	<350
Pulse duration (ns)	1000 ns-FT	1000 ns-FT
Energy in magnet (J)	0.100 [0.352]	0.208 [0.492]
Impedance (Ohm)	25	25
Inductance (μH)	2.8	3
Drive voltage (kV)	13.4 [25.1]	18.6 [28.6]
Pulse to pulse stability (%)	±0.1	±0.1
Flatness (%)	±1	±1

The pulsed magnet system in TPS comprises three major sections, including the booster injection, the electron beam extraction and BTS (booster to storage ring) [1]. There are one booster injection septum and one kicker in booster injection section. The booster extraction section consists of two booster extraction kickers and two septa. After booster extraction, the electron beam passes through the BTS section, which is composed of four kickers and two septa. Table 1 shows the parameters of booster injection and extraction kickers in TPS.

THE INSTALLATION PROCESSES OF THE KICKER

In order to achieve the precision of support and convenience of kicker assembling, two aluminium plates are used to increase the assembling reliability. The processes of assembling are shown as Figure 2, 3 and 4 in series.

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-WEPRO014

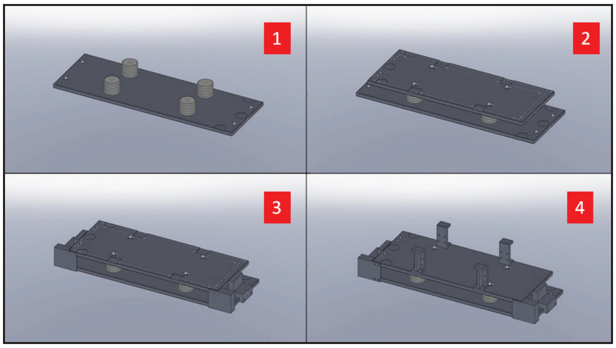

Figure 2: The kicker base assembling steps.

The kicker base plates are assembled as Figure 2 shows. The base consists of two aluminium plates with four ceramic columns screwed between them. The pin holes on the plates are used for positioning and measurement. For the limitation of CNC accuracy, the position error will be less than 0.01 mm. The Figure 2-3 shows the assembling of four fixtures. These fixtures prevent the misalignment while composing other parts. The brackets fixed on the upper plates are used for ferrites positioning.

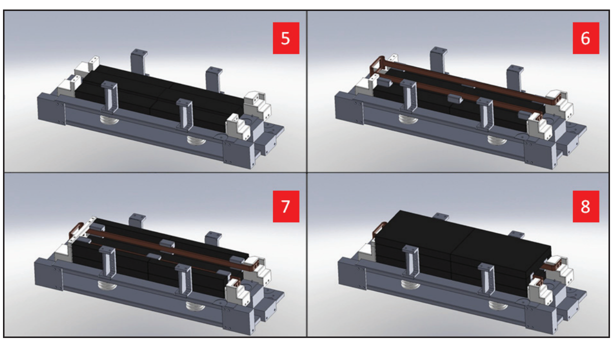

Figure 3: The magnet assembling steps.

After lower ferrites placed on the upper plate, the ceramic blocks are fixed to the edge of upper plate then. (Refer to Figure 3) These ceramic blocks are designed to ensure the position of ferrites and coil. By using the brackets and the ceramic blocks, the ferrites and coil are fixed firmly and precisely. The ceramic stuffs between coil and ferrites reduce the vibration resulting from pulsed power firing. According to magnetism, the contraction of coil will affect the accuracy of magnetic field obviously. More robust structure acquires more homogeneous magnetic field.

The magnet is assembled with eight pieces of ferrites. Before fasten up the ferrites, make sure all parts are pushed to the alignment sides tightly. After fasten up the top lumps and remove the fixtures, slide the whole magnet and the aluminium base into the vacuum chamber as Figure 4-11 shows. Finally, install the feedthroughs and the L-shaped copper buses, the assembling of the booster injection kicker will be completed. Notice that top lumps and L-shaped copper buses are screwed with spring washers in case of loose from vibration.

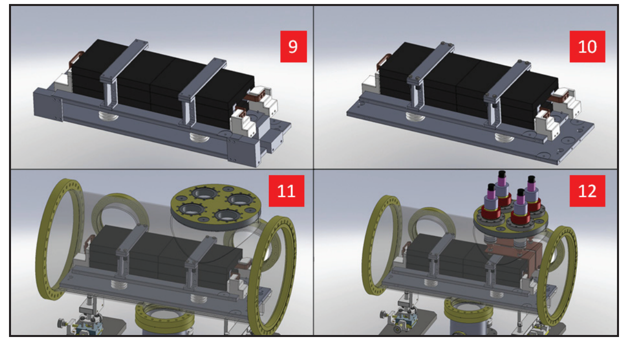

Figure 4: The accessories assembling steps.

EXPERIMENT AND TEST RESULTS

A lot of experiments have been done before all kicker parameters are decided. In this article, it focuses on preventing electric arcing and reducing the inductance of magnet.

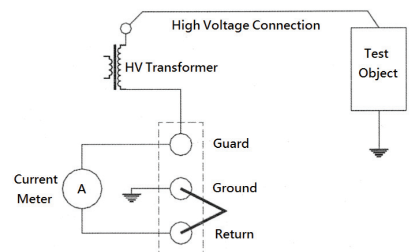

Figure 5: AC withstand voltage test setup.

In this article, an AC withstand voltage test is proceeded and its set up is as shown in Figure 5[2]. The AC dielectric test sets are Model 6CP100/50-7.5 from the Phenix technologies. This portable AC high voltage test equipment is suited for use in field or in the laboratory. Its voltage output ranges from 0~50kV and 0~100kV depending on the selection of output port. The kicker system, test object in this test, is applied with an AC high voltage about 10 ~ 25kV. Total current including all stray current will be collected by the current meter.

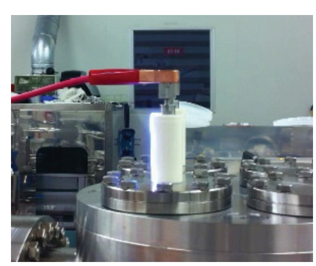

Figure 6: AC withstand voltage test of ceramic columns.

The ceramics are used as electric insulators commonly. For the limitation of vacuum chamber space, the size of ceramic column must be trimmed while without any function loss. According to our measurements, intervals bigger than 40 mm could sustain at least 30 kV without voltage arcing. The size of ceramic columns is decided to be 40 mm. In order to increase creepage distance, the wavy surface is designed on the ceramic columns as well.

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-WEPRO014

Figure 6 shows the arc appears at the brief moment while the voltage breakdown.

The distance between conduction coil and ground is another critical problem. As mentioned above, the design of booster injection is as in-vacuum type, which means the surrounding chamber wall will be grounded and increases the paths to short circuit. To reduce the probability of short circuit happens, it is concluded by the following experiments. The shape and distance of the electrodes affect the value of withstand voltage. Refer to Figure 7, the blue lines represent the data from right-angled electrodes while the red ones represent the chamfered electrodes. It is obviously that the breakdown voltage and the leakage current increase along with the distance increase between electrodes and ground. A chamfered electrode sustains at least 25 kV without significant leakage current and the withstand voltage reaches 37.5 kV. Therefore, it leads to the conclusion that the minimum interval between high potential parts and ground within the chamber is 30 mm. Besides, all edges of coil must be chamfered at least R2 (the same case with red-dot line in Figure 7).

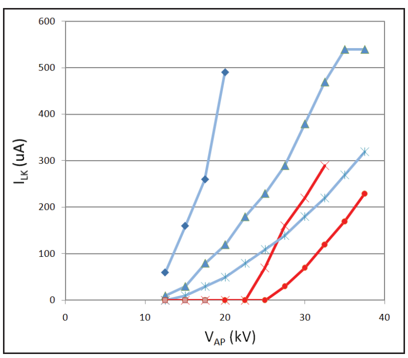

Figure 7: Leakage current in different situations.

The roughness of the electrode surface affects the behaviour of electrical discharge, too. The copper coil was made without bright polish at first. Refer to Figure 8, the difference can be easily observed with microscope. The roughness of the coil surface before polish, Ra is measured 1.78 µm in average while Ra’ measures 0.03µm in average after bright polish. The withstand voltage after bright polish increases to 30 kV instead of 22.5 kV which coil polished only by sandpapers.

Under the precondition of sufficient insulation, reducing the distance between inlet and outlet feedthroughs and increasing the width of the L-shaped bus will acquire less inductance. The ordinary coil is 80 mm wide, and the inductance is 3.29 µH. By reducing the width from 80 mm to 65 mm, the inductance decreases to 3.02µH. And furthermore, the wide L-shaped bus can reduce the inductance to 2.96µH.

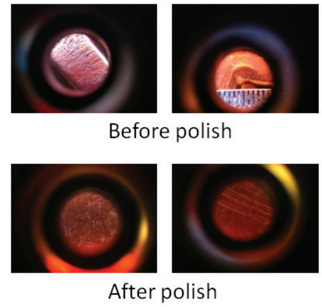

Figure 8: Surface roughness observed with scope.

For the given geometry of the magnet and coil setup, the inductance (L) of the coil can be determined by Eq. 1.

$$\mathrm{L} = \frac{\mu_0 \cdot w \cdot l}{h} \qquad \text{(Eq. 1)}$$

Where w is the distance between two centers of the conductors, and l is the length of the magnet, h is the height of the air gap[3]. Since the l and w are fixed in a given ferrite set. Increasing the h will also reduce the inductance. But a wider air gap will increase the driving voltage, for this reason, the final version of L-shaped bus size is 65 mm wide, broad L-shaped copper bus. (see right picture in Figure 9)

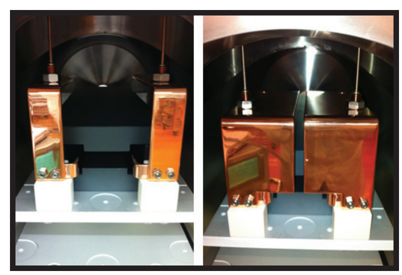

Figure 9: Different size of the L-shaped copper bus.

CONCLUSION

In this article, some different cases have been done to verify which parameters affect the breakdown voltage and will acquire the minimum inductance. The experiment results provide us the guidelines to define these proper dimensions for kicker system. Both coil and supports obey these rules to prevent failures during operation.

REFERENCES

[1] Y.-H. Liu et al., “TPS SR Kicker Prototype Installation Status”, IPAC11, 2011.
[2] C.-S. Chen et al., “The Leakage Current Induced by Stray Capacitance in the Pulse Magnet System.”, IPAC13, 2013.
[3] C.-L. Chen et al., “The Influence of Kicker Inductance on the Performance of a PFN Power Supply.”, NSRRC, 2013.