PRODUCTION OF EXTRACTION KICKER MAGNET OF THE J-PARC 3-GeV RCS

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Abstract

To improve reliability of the RCS for user operation, production of a reserve kicker magnet has been performed. The kicker magnet mainly consists of Ni-Zn ferrite cores and Aluminium alloy plates, and these parts are installed in vacuum chamber to prevent discharge because a high voltage is applied to the magnet for a short period. Since it is important to reduce the outgassing of water vapour from these parts to prevent discharge, we has been produced the reserve magnet with low outgassing at high voltage discharge. Since assemble of the kicker magnet already finished and vacuum test has been performed.

INTRODUCTION

The J-PARC 3-GeV rapid cycling synchrotron (RCS) has been provided proton beam to the Material and Life Science Facility (MLF) as well as to the 50 GeV Main Ring (MR). Proton beam is accelerated from 181 MeV to 3GeV in the RCS and immediately extracted it to the beam transport line to the MLF and the MR. Extraction kicker magnets are used for this fast extraction. The RCS was also severely damaged by the earthquake on March 11^{th} and beam was shut down [1]. The recover work proceeded and thanks to the great efforts of staff members and help of support, the accelerators restarted user operation from January 2012. Beam power smoothly recovered and high power beam could deliver to the MLF and to the MR with more than 300 kW in December 2012.

In that earthquake only the accelerator components in the yard suffered serious damages, the damage of the other components was fortunately not so serious. Since the extraction kickers were also no damage, it was possible to restart accelerator operation. If there was serious damage of the extraction kickers it was impossible to resume operation of the RCS for users, because we had no spare kickers at all. Form this reflection and also to improve reliability of the RCS for user operation, production of a reserve kicker magnet has been performed. Since assemble of the kicker magnet already finished and vacuum test has been performed, the result of vacuum test is reported.

STRUCTURE OF KICKER MAGNET

Table 1 shows the specifications of the RCS extraction kicker magnet and vacuum chambers. There are totally eight with three types of kicker magnets, S, M, and L, corresponding to their vertical aperture sizes. These eight magnets are installed in the RCS by divided into 2 vacuum chambers. One vacuum chamber has three kickers (L, M, and S), and the other has five magnets (2Ss, M, and 2Ls).

Table 1: Specifications of Kicker Magnets

Numbers		8 ; S:3, M:2, L:3
Characteristic impedance [Ω]		10
Excitation current [kA]		6 kA
Applied Field [kV]		30 kV
Magnetic field [T]		0.048(S),0.043(M), 0.037 (L)
Dimension [mm]	Vertical	960
	Horizontal	776
	Length	638
Aperture size [mm]	Vertical	153 (S). 173(M), 199(L)
	Horizontal	280
	Length	630
Magnetic core		Ferrite
Unit number [units/magnet]		20

Figure 1 shows the appearance and outline structure of a kicker magnet. The main materials of the magnet are Ni–Zn ferrites, whose nominal composition is AFe_2O_3 (A = Ni and Zn), and aluminium alloy (A5052). This ferrite has good high-frequency properties, so it is used as the magnetic core. Relative permittivity of the ferrite core is 17–25. Aluminium alloy is used for high voltage (HV) electrode plates, earth plates, and conductors for exciting current. The HV electrodes are mounted on a alumina ceramics (Al_2O_3) bases. The ferrites are put together into C-shape cores facing each other, the so-called twin-C type. The ferrite core and an aluminium earth plate are inserted between the aluminium HV electrode plates. These parts form one unit of a distributed parameter line (transmission line), twenty units constituting one magnet. The distance between the HV electrode and earth plate is 6.5 mm. Central earth plates are inserted between the C-shape cores as shown in Fig. 1 to prevent the magnetic field from penetrating into the other side of the cores. The distance between the HV electrode and the central earth plate is 22 mm. The maximum electric field strength on the HV electrode plate, being several kV/mm, is generated at the contact point to the ferrite core. The electric field strength on the ferrite surface is tenth of kV/mm. To reduce discharge the corner of the HV electrode was covered by alumina ceramics mount. This fitting structure also plays a role in positioning the HV electrode plates. As a result, there was no trace of discharge. The other characteristics are as follows. As shown in Fig. 1, conductors are sandwiched between HV electrode plates. Conducting bars are introduced through

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them. The conductors and HV electrode plates are put into contact with each other by fastening nuts at both sides of the conducting bars. Nevertheless, spark discharge occurred in the small gap between the nuts and the HV electrode or between the conductors and the HV electrode. Therefore, flat washers were additionally inserted as spacers between the nuts and HV electrode plates to eliminate the small gaps to suppress spark discharge generated in small gaps between the conducting parts.

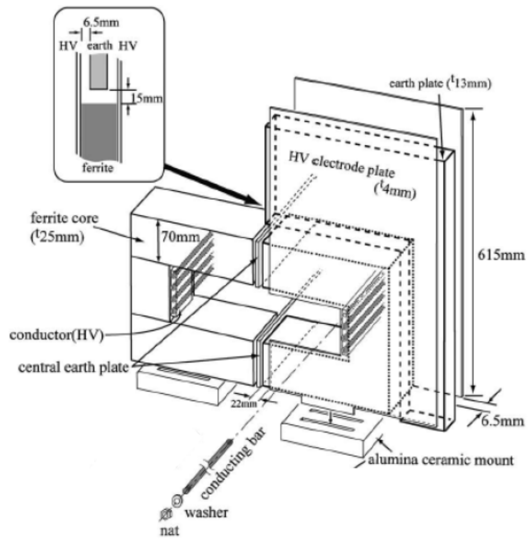

Figure 1: Outline structure of the kicker magnet.

REDUCTION OF OUTGASSING

Reduction of outgassing from magnet components is very important to suppress not only discharge but also beam scattering by the residual gas. Especially, suppressing the outgassing from aluminium alloy and ferrite core is indispensable since they have large surface areas of 35 m^2 and 5 m^2 per magnet, respectively.

1) Aluminium alloy

We finished the surface of the aluminium alloy by pit-free electro-polishing [2]. In this process, reactant hydrogen gas, which causes pits on the aluminium surface, is removed by the flow of electrolyte solution generated by plate blades. Therefore, pits are not generated by reactant gas bubbles and a smooth surface can be achieved.

Pictures of aluminium alloy surface which was treated by two kinds of pit-free electro-polishing are shown in Fig. 2. One method is used for the aluminium alloy plate of this kicker and the other is used for the ones of the kicker used for user operation (called previous method). The roughness was measured by confocal lase microscope. An average roughness of this aluminium alloy was about 90 nm and it of the previous one was 140 nm. It was found that the pit-free electro-polishing method which was used for the aluminium alloy plate of this kicker magnet had good performance compared to previous method.

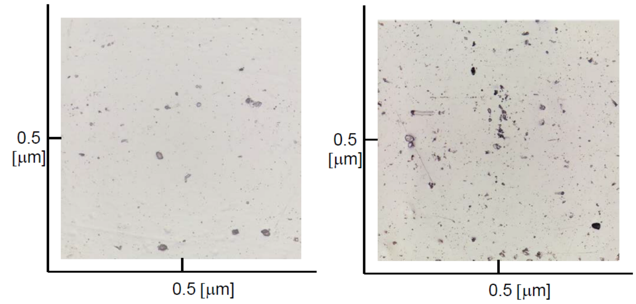

Figure 2: Pictures of aluminium alloy surface which was treated by two kinds of pit-free electro-polishing. (1); aluminium alloy for this kicker magnet, (2); aluminium alloy for the kicker magnets used for user operation.

Figure 3 shows an atomic concentration in-depth of the aluminium alloy which was treated by two kinds of electro-polishing methods. These were measured by Auger electron spectroscopy. The thickness of the oxide film of the aluminium alloy was estimated from these data. The thickness of the oxide film was less than 20 nm in both methods.

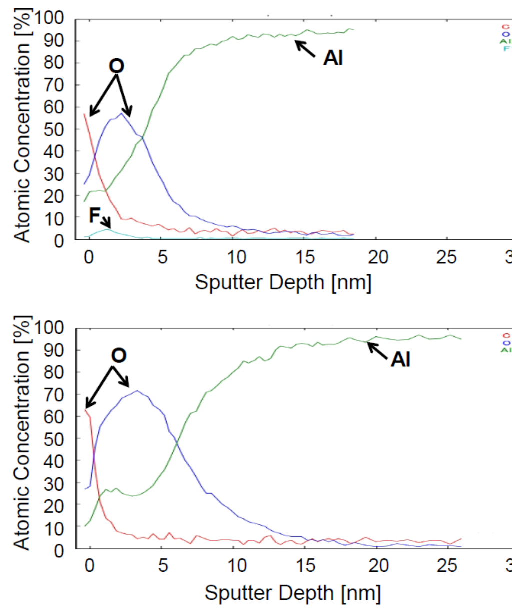

Figure 3: Atomic concentration in-depth of the aluminium alloy with electro polishing. Horizontal shows supper depth from the surface of the aluminium and vertical shows atomic concentration. (1) aluminium alloy for this kicker magnet, (2) aluminium alloy for the kicker magnets used for user operation.

2) Ferrite

PE14 produced by TDK was used as the ferrite core. We have decided to construct the reserve magnets with very low outgassing at high-voltage discharge. First of all, the thermal desorption behavior of the ferrite was investigated. Water vapour has two peaks: at 150 °C and 300 °C. Carbon dioxide is rather largely emitted with the peak around 275 °C and then decreases with the temperature. From these results, the ferrite cores were

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vacuum-fired at 450 °C for 48 h. Then the good properties for the magnetic cores were confirmed [3].

ASSEMBLING AND VACUUM TEST

Kicker magnet was assembled in a clean room to keep cleanse of all parts using for the kicker. Typical assembling process shows in Fig. 4. One of most important process is how to decide position of ferrite core on alumina ceramics basis. Straight edge of the aluminium alloy plate and telescope were used to do it. After 20 units of ferrite and aluminium alloy plate, two high voltage electrodes were fixed with ceramics rods. Side plates, earth plates, outer ceramics plates, and electrodes were fitted in a sequential order, and finally high voltage connectors were attached.

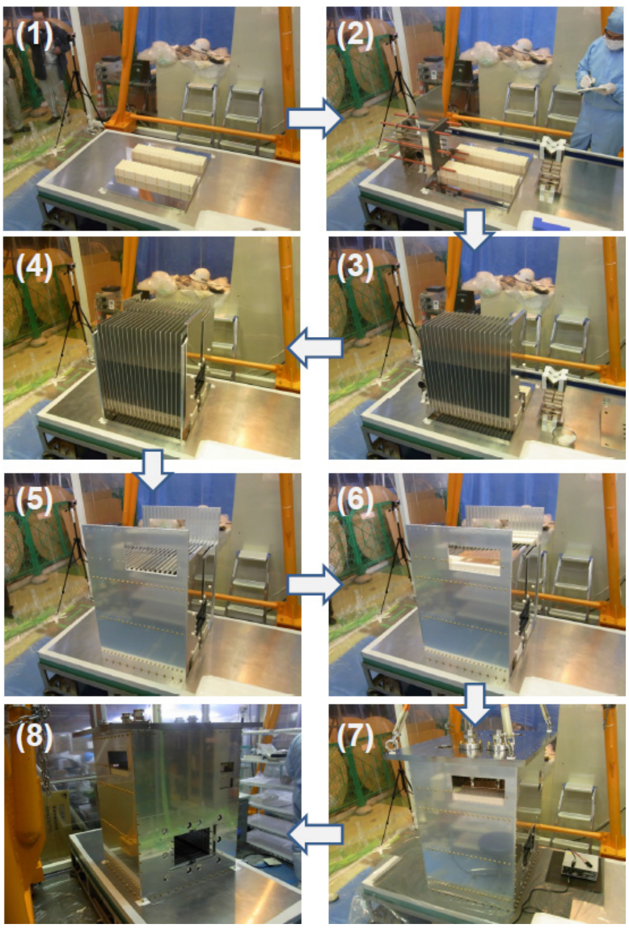

Figure 4: Assembling process of the kicker magnet. (1) Setting of ceramics base blocks on a base plate. (2) Setting of aluminium alloy plate and ferrite on the ceramics base blocks. (3) Fix of the aluminium alloy plate and ferrites with ceramics rods. (4) Setting of high voltage plate (5) Setting of side plates and earth plates. (6) Setting of outer ceramics plates and high voltage electrodes. (7) Attached high voltage connectors. (8) Complete od assembling of the kicker magnet.

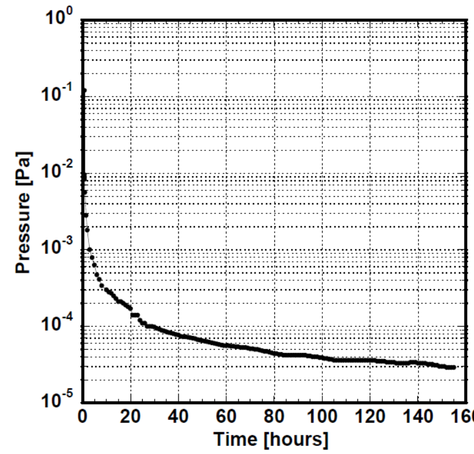

Figure 5: A pumping-down curve from atmospheric pressure.

Vacuum test of this kicker magnet was performed. A pumping-down curve from atmospheric pressure is shown in Fig. 4. The turbo-molecular pump (TMS) with dry roughing pump is used for this test. Pumping speed of the TMP is 350 l s^{-1} for N_2. Outgassing rate is estimated at $3.5x10^{-7}$ Pa m s^{-1} by the pumping data.

The kicker magnets used for the user operation were backed in the temperature at 150 °C for 50 hours after installation of the vacuum chamber in situ. Before bake out the outgassing rate of the kicker magnet is about $1x10^{-6}$ Pa m s^{-1} and the outgassing rate is reduced to 8.0 x 10^{-8} Pa m s^{-1} after backing [4]. Since the pressure level of the RCS reaches less than 10^{-5} Pa in one day, it is sufficient satisfied outgassing rate for new kicker magnet.

Since it is important to satisfy specification of magnetic field, now we are preparing to measure magnetic field of this kicker magnet.

SUMMARY

To improve reliability of the RCS for user operation, production of a reserve kicker magnet has been performed. Treatment conditions of aluminium alloy and ferrite which are main parts of the kicker magnet were decided to reduce outgassing from the kicker magnet. Outgassing rate from the kicker magnet was about $1x10^{-6}$ Pa m s^{-1}, and this was sufficient small to use for user operation. Measurement of magnetic field of this kicker magnet is now preparing.

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