RESULTS OF THE MAGNETIC FIELD MEASUREMENTS OF THE DTL QUADRUPOLE MAGNETS FOR THE J-PARC

E. Takasaki[#], F. Naito, H. Tanaka, K. Yoshino, KEK, Tsukuba, Japan
T. Ito, JAERI, Tokai, Japan
H. Ino, Z. Kabeya, S. Kakizaki, T. Kawasumi, MHI, Nagoya, Japan

Abstract

A quadrupole electromagnet is installed in the drift tube, which has an outer diameter of 140 mm and its minimum length of 53 mm. Hence, a coil of this magnet was made by the advanced periodic reverse copper electroforming method (PR-method) instead of the conventional hollow conductor. 149 quadrupole electromagnets were completed and then installed in the drift tube within a high accuracy. The magnetic field measurements have been carried out by a rotating coil at each stage of the manufacturing process of the drift tube. The discrepancies between the magnetic field center and the mechanical center are within about ± 25 μm after installation of the quadrupole magnet inside the drift tube. Recently, drift tubes have been aligned into 9 unit-tanks. This paper describes results of the magnetic field measurements and summarizes results of the drift tube alignments in the unit tanks.

INTRODUCTION

The Alvarez-type drift tube linac (DTL) accelerates the H^- ion beams from 3 MeV to 50 MeV. It consists of the three tanks (DTL-1, DTL-2 and DTL-3), of which the length is about 9 m. Each tank is composed of three short unit tanks. The inner diameter of the tank is 560 mm.

The 149 drift tubes, in which an electromagnetic quadrupole magnet (Q-magnet) is installed, are aligned into DTL precisely within the required accuracy. The specifications of all the Q-magnets in the DTL are given in Table 1 with the size of the drift tube.

Now all the magnets have been completed and installed into the drift tubes (DT). All the drift tubes have been aligned into the 9 unit tanks within the high accuracy of ± 50 μm, which was determined from requirement of the beam dynamics. The first tank (DTL-1) accelerates the H^- ion beam from 3 MeV to 19.7 MeV, successfully.

CONSTRUCTION OF QUADRUPOLE

Since the resonance frequency of the DTL is 324 MHz, the size of the DT becomes smaller. The pulsed Q-magnet is selected to suppress deformation of the DT by the released heat of the coil. Hence, as a coil, the electroformed hollow coil [1-3] has been developed at KEK. Furthermore, beam dynamics requires that the deviation of the quadrupole center from the mechanical center should be within ± 50 μm. Hence, we decided on ± 25 μm as a tolerable deviation of the magnetic field center from the mechanical center of the Q-magnet and the DT. Figure 1 shows some components for the Q-magnet.

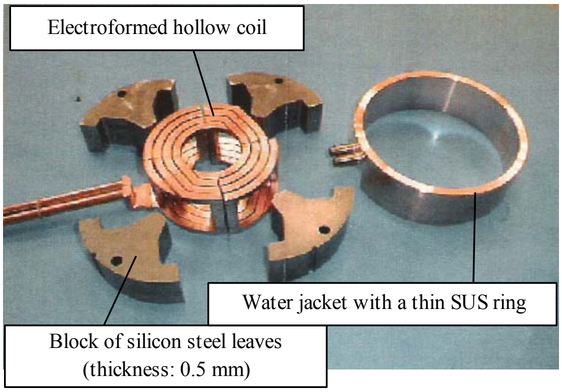

Figure 1: Components for the Q-magnet

Especially, the water jacket with a thin SUS ring has been used to fasten four long blocks together with thermal shrinkage of a water jacket.

The magnetic field of the Q-magnet has been measured by a rotating coil to investigate if the deviation of the magnetic field center from the bore center would be within the required accuracy. The measured results are shown in Figure 2. As seen in the Fig. 2, the discrepancies of all the magnets are within ± 25 μm.

Table 1: Specifications of all quadrupoles in the DTL

DTL tank	DTL-1					DTL-2		DTL-3
DT Nos.	1 to 6	7 to 23	24 to 56	57	58 to 77	78	79 to 121	122 to 149
Type of Q-mag.	A type	B type	C type		D type		E type	F type
Outside diameter of Q-mag./ DT (mm)	115/140	115/140	115/140	115/140	115/140	115/140	115/140	115/140
Core length (mm)	33	35	50	76	80	80	90	125
Bore diameter (mm)	15.6	16	16	21	21	25	25	29
Number of magnets	6	17	33	1	20	1	44	28
Inside diameter of beam pipe (mm)	13	13	13	13|18	18	22	22	26

[#] eiichi.takasaki@kek.jp

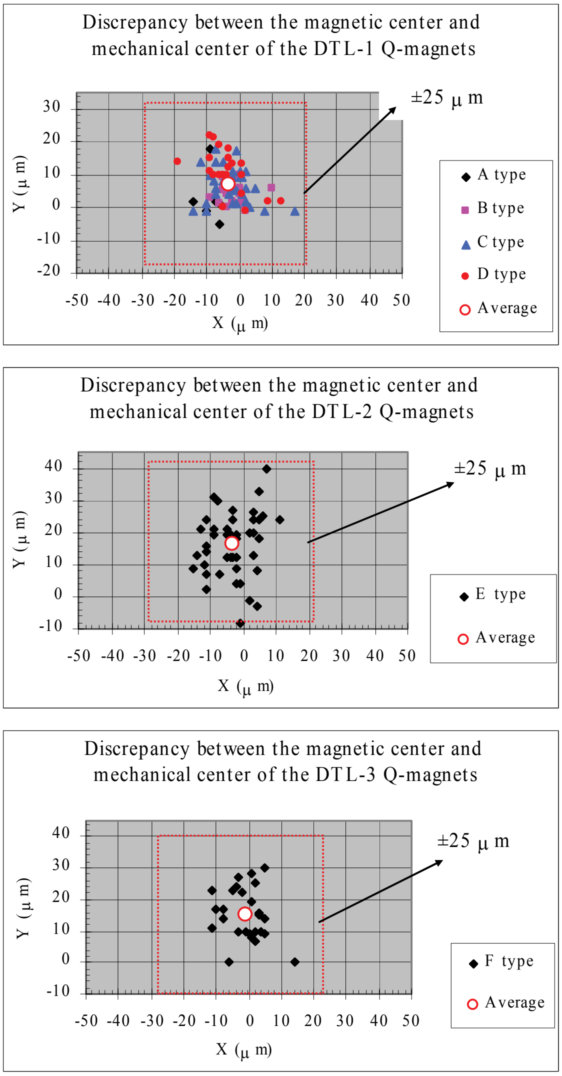

Figure 2: Measured discrepancies between the magnetic field center and the mechanical center of the Q-magnet.

DT FABRICATION

The drift tube was assembled with a Q-magnet, a stem (34 mm in diameter) and some components, which were two drift tube shells, a beam pipe and a stem base made of stainless steel. The size of the drift tubes is given in Table 1.

The manufacturing process of the drift tube is described as follows. At first, a Q-magnet is installed in the standard drift tube shell with a high accuracy in order to transfer the mechanical center from the bore of the Q-magnet to the inside of a beam pipe of the DT. Secondly, another shell and a stem base are assembled and then are welded by an electron beam welding (EBW). A stem is also welded by TIG-welding. After this process, the magnetic field measurement is carried out for checking the position shift of the magnetic field center by the thermal stress due to the EBW and the TIG-welding. In practice, we have observed the position shift after the EBW of the stem base. Hence, the beam pipe has reclaimed for correcting the measured discrepancy. Thirdly, the copper having thickness of over 1 mm is electroformed all over the surface of the drift tube except the inner surface of the beam pipe by the PR-method. And then the surface is precisely machined to obtain the proper size. Fourthly, the drift tube is impregnated with the epoxy resign by the vacuum impregnation method and finally the surface of the drift tube is electro polished (EP) in order to remove abrasive particles and denatured layers. At this stage, the DT is completed. After completion of the DT fabrication, we have measured the discrepancy between the magnetic field center and the mechanical center, which means the center of the inside of the beam pipe. The measured discrepancies are shown in Figure 3. Figure 4 shows the magnetic field measurement system.

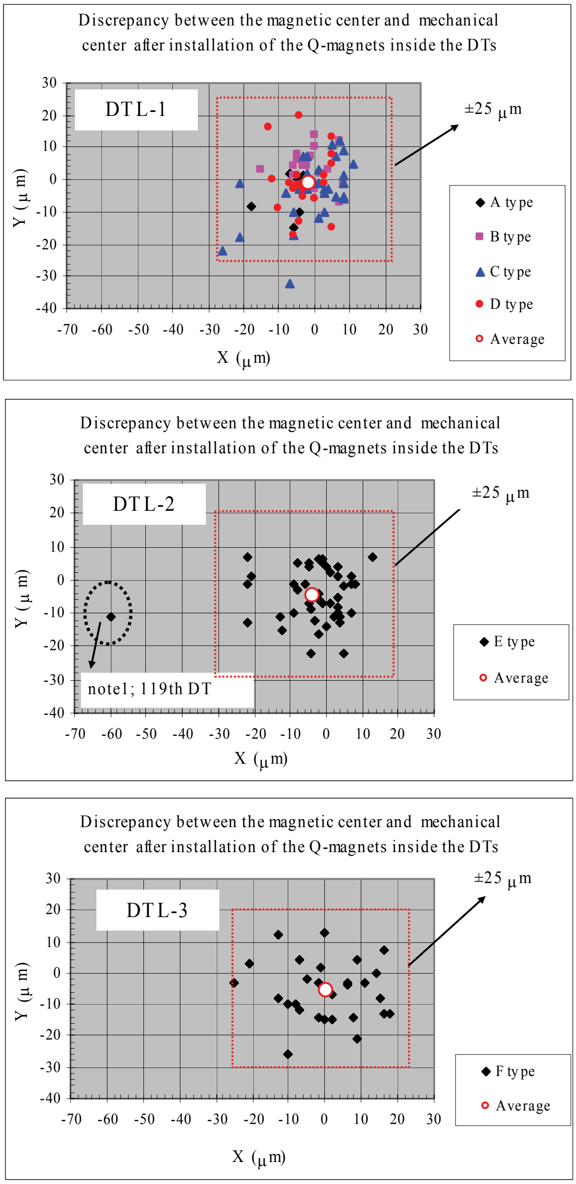

Figure 3: Measured discrepancies between the magnetic field center and the mechanical center of DTs.

Unfortunately, we observed the bad discrepancy for the 119th DT. This bad discrepancy (-60 μm for the 119th DT) would be caused by an impact during the transportation process. This accident happened before the magnet was finally fixed inside the drift tube and the coil was completely insulated by the vacuum impregnation of the epoxy resin. Hence, the discrepancy of 119th drift tube will be corrected when the drift tube will be aligned in the tank (DTL-2).

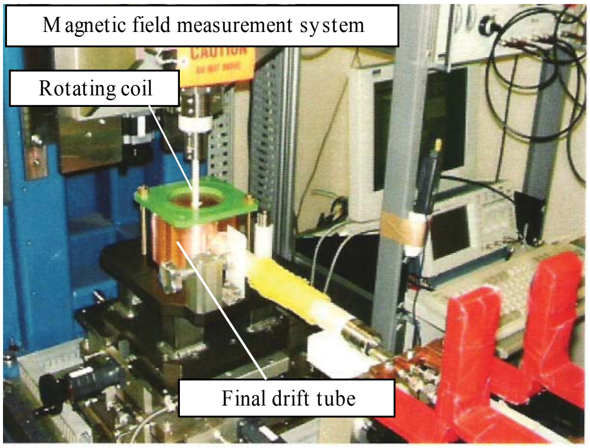

Figure 4: Magnetic field measurement after the final fabrication process.

DT ALIGNMENT

It is most important to align the drift tubes in the tanks with a high accuracy. The required tolerance of the alignment errors is ± 50 μm in the vertical plane (X-Y plane) to the beam axis and ± 100 μm along the beam axis (Z-axis). At first we have set up the optical telescope for fixing an optical axis, which is the center of the unit tank, by installing the templates at the extremities of the tank. The optical target has been installed inside the beam pipe and the DT has been aligned by using the optical telescope. The center position has also been measured by the optical telescope. The position of the DT along the beam axis has been measured by the laser interferometer and the special instrument for the z-measure. The systematic error in this alignment system has been estimated to be within about ± 10 μm. Hence, we have estimated that total systematic error in the procedure aligning the magnetic field center would be within about ± 18 μm, considering the errors in the magnetic field measurement system.

The aligned results are shown in figure 5. Figure 5 shows that all the drift tubes are sufficiently aligned with the required accuracy of ± 50 μm within the estimated errors.

Now, the DTL-1 accelerates the negative hydrogen beams from 3 MeV to 19.7 MeV with a beam intensity of about 30 mA, successfully [4]. As for the DTL-2 and the DTL-3, adjustment of tuners is carried out in order to obtain the uniform accelerating field on the beam axis. Furthermore, the post-couplers also are adjusted to stabilize the accelerating field distribution [5].

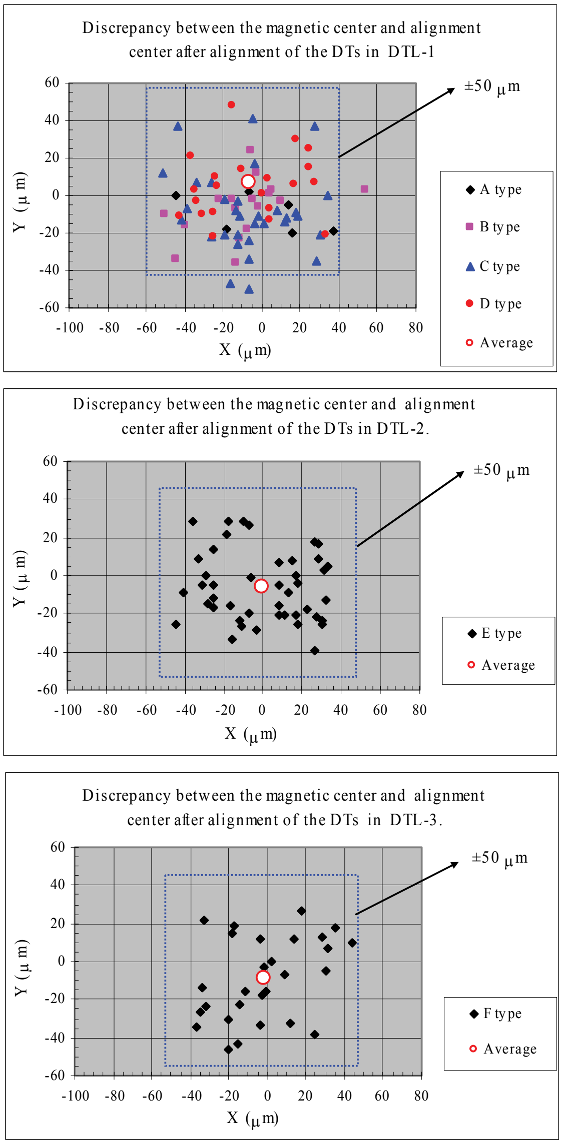

Figure 5: Discrepancies after all the drift tubes are aligned in the tank.

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