Fabrication of a Prototype Drift Tube based on Permanent Magnet Array

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1. Introduction

A 100-MeV proton linear accelerator at KOMAC uses drift tube linac (DTL) structure to accelerate proton beam from 3 MeV to 100 MeV. Total number of drift tubes used for acceleration up to 20 MeV is about 150 and every drift tube includes electromagnetic quadrupole (EMQ) for focusing. Because the space available for a magnet installation in the drift tube is quite limited, we cannot use hollow conductor to make EMQ. Instead, the EMQs were made of simple enamel wire, which is typically used for making a transformer. The cooling of the EMQ is achieved by water flowing around the magnet winding. After several years of operation, some EMQs suffered from failure, especially due to electrical short between layers of magnet winding (see Fig. 1). It causes degradation of beam transmission along the linac. Moreover, it takes a lot of time and labor to replace the failed DT during maintenance period.

To enhance the DTL reliability, a prototype drift tube based on a permanent magnet quadrupole (PMQ) is designed and fabricated to replace the EMQ. In fact, most high-intensity proton linear accelerators, such as SNS in US, ESS in Europe and LINAC4 at CERN, took advantage of using PMQ based drift tube [1-5]. The designed PMQ is assembled from 16 segments, which are made of Sm2Co17 magnetic material for its radiation hardness, resulting in the integrated field gradient of about 1.6 T. We performed a design study on the PMQ to replace EMQ in 20 MeV DTL at KOMAC including magnetic analysis and beam dynamics effects. A prototype drift tube based on the permanent magnet was fabricated and is ready for magnetic field measurement.

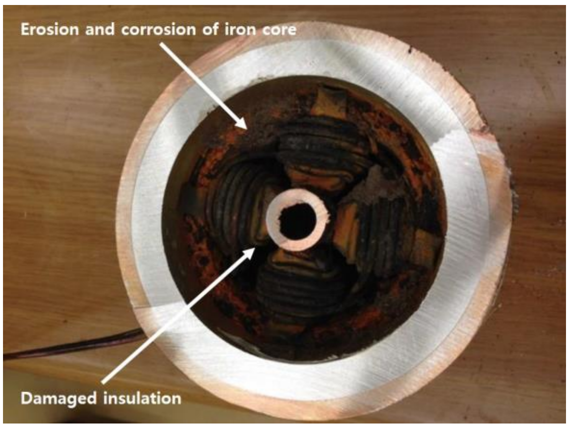

Fig. 1. Cut-view of the failed drift tube, showing the damaged insulation and corroded iron core.

2. Design Study

From the view point of beam dynamics, the integrated field gradient should be matched to successfully replace the EMQ with the PMQ. The iron yoke thickness of EMQ is 25 mm, while the permanent magnet used for the design is 30 mm. The 2D magnetic field analysis using POISSON code showed that contents of first allowed harmonics (dodeca-pole component) of PMQ is almost two-order of magnitude less than that of EMQ. This is mainly due to the lager distance from the axial center to pole magnet (inner radius of the PMQ is 20 mm, while the distance to the pole tip in EMQ is just 10 mm).

By using CST EMStudio, we calculated the magnetic field for both of EMQ and PMQ, as shown in Fig. 2. The peak magnetic field of PMQ is about 10% less than that of EMQ but the effective length of EMQ is larger by same amount so that the integrated field gradient is same for both types of magnet. Same integrated field gradient means same beam behavior in the quadrupole channel, which was confirmed by TRACE3D calculation as shown in Fig. 3.

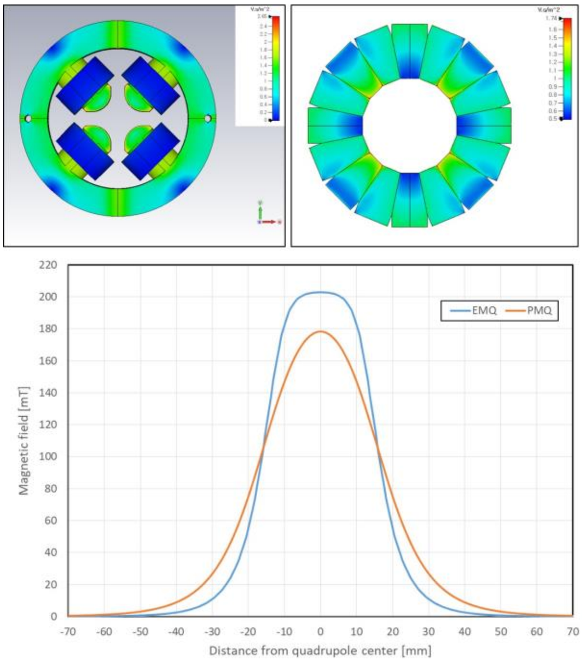

Fig. 2. Comparison between the EMQ and the PMQ (upper left: magnetic field distribution in EMQ, upper right: magnetic field distribution in PMQ, lower: magnetic field profile along the beam axis with 4.4 mm offset in radial direction).

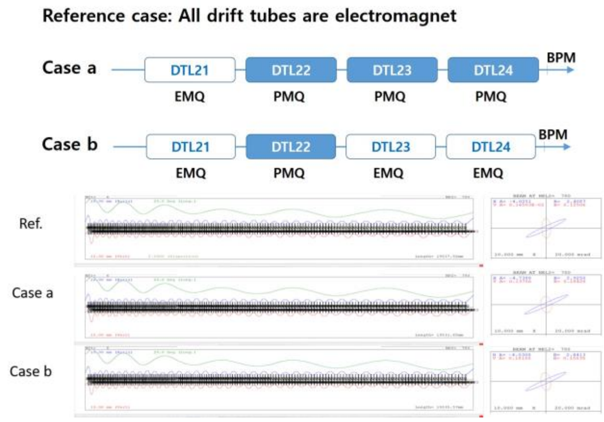

Fig. 3. Beam dynamics effect by changing the EMQ to the PMQ (reference case: all drift tubes are EMQ, case a: all drift tubes except first DTL tanks are changed to PMQ, case b: drift tubes in second DTL tank are changed to PMQ, while the others are EMQ)

3. Fabrication Status

Based on the beam dynamics calculation and magnetic field analysis, we fabricated a prototype drift tube with PMQ. Overall design of the prototype drift tube can be seen in Fig. 4. We chose Sm2Co17 permanent magnet (Vacomax 225HR) with consideration of minimizing field strength loss due to neutron fluence. High strength aluminum alloy (7075-T6) was used as magnet housing material to minimize housing distortions due to set screw load on pole pieces. The fabricated PMQ and pre-assembled drift tube is shown in Fig. 5. We are going to measure the magnetic field profile before final assembly step by using electron beam welding (EBW) process. After final assembly, we will measure the magnetic field again and we can check the EBW effect on the field quality.

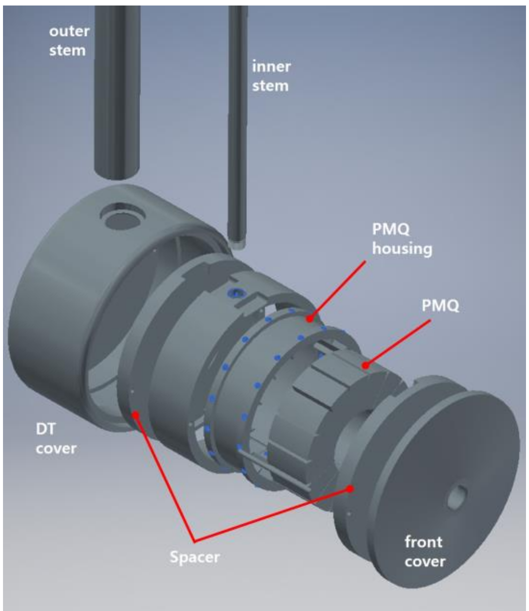

Fig. 4. Overall design of the prototype drift tube.

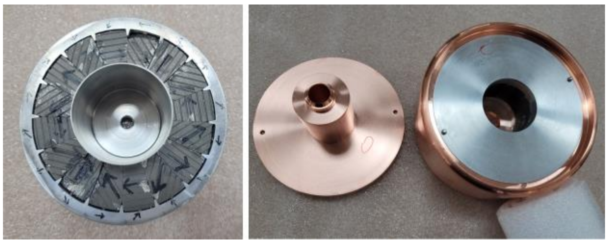

Fig. 5. Fabricated PMQ and pre-assembled drift tube.

ACKNOWLEGEMENTS

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