Fabrication and Operation Test of Beam Wobbler Using Halbach Dipole Magnets for KOMAC RI Production Beamline

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1. Introduction

The Korea Atomic Energy Research Institute plans to produce various radioactive isotopes using 100-MeV proton accelerators located in Gyeongju [1]. For this purpose, a target room surrounded by thick concrete walls for radiation shielding is provided. In this target room, proton beam irradiation of up to 100 MeV 30 kW is possible. However, if proton beams with diameters of several mm are irradiated directly on RI production targets, the targets are highly likely to be damaged due to the high thermal load density. To avoid this, a method is used to reduce the thermal load density on the target surface by spreading the proton beam widely.

The usual way to spread the beam is by wobbling. For 100-MeV protons, the electrostatic type cannot be used due to the size of the device, so the magnetic type is used. However, because it is difficult to obtain high magnetic flux density when using alternating current electro-magnet, the size of the alternating current electro-magnet increases and the production of current power supply becomes difficult. It is determined that it would be difficult to produce conventional wobblers in the RI beamline and the target room of the 100-MeV proton accelerator, so it is decided to use rotating dipole permanent magnets instead of alternating current electro-magnets.

2. Design

In order to efficiently create a dipole magnetic field in a limited space, a wobbler was designed using Halbach-type permanent magnets. It is designed by using two magnets to obtain a suitable wobbling radius for target size, independent of the distance between the wobbler and the target. The rotational speed is set as high as possible to the extent that the magnetic field induced by the eddy current generated over the beam pipe made of stainless steel does not affect the magnetic field originally made by permanent magnets [2].

The permanent magnets were made to rotate by a motor and a V-belt using a pulley installed between the two magnets. The wobbler is installed inside the target room, so the effects of radiation should be minimized. Materials that are resistant to radiation damage and have less neutron activation are used. The wobbler is designed to be as simple as possible to facilitate maintenance. Figure 1 shows the final three-dimensional design drawing for the fabrication.

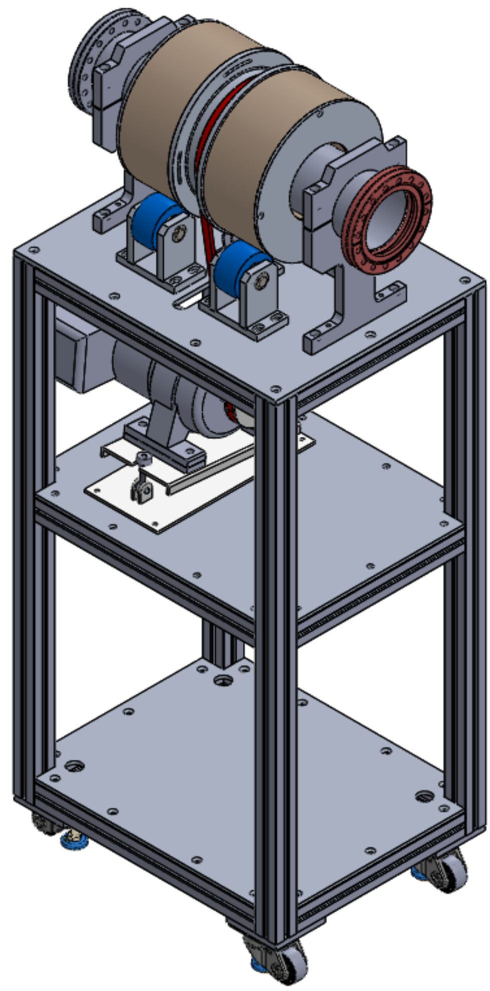

Fig. 1. Final three-dimensional design drawing of the Beam Wobbler Using Halbach Dipole Magnets.

3. Fabrication

Photo 1 shows the wobbler made according to the drawing. Figure 2 shows the measurement result of the magnetic field of the central axis of the wobbler magnet combined with the two permanent magnets. It was confirmed that the magnetic fields of the two permanent magnets were symmetric from side to side with a 180 degree phase difference. After running the motor and turning the wobbler at a rotational speed of 180 rpm for more than an hour, it was found that the temperature of the beam pipe increased slightly due to the eddy current enough not to be a problem.

Since the permanent magnets were not originally true circle, Eccentricity was inevitable in the process of combining the two into one. This results in vibrations of less than 1 mm amplitude.

Photo. 1. Fabricated beam wobbler in test operation.

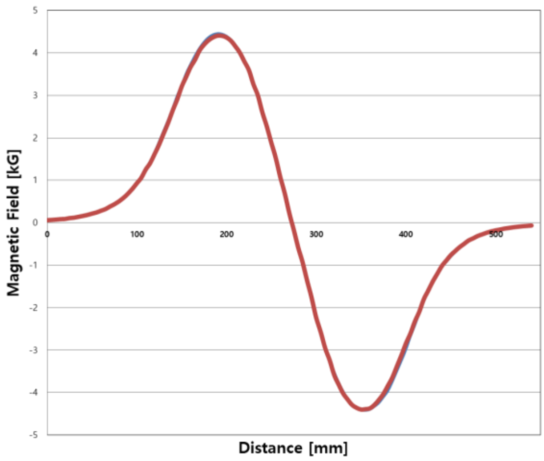

Fig. 2. Measured magnetic field of the central axis of the wobbler magnet.

4. Analysis of Vibration Effect

The oscillation of the wobbler magnet is possible in two modes as shown in Figure 3: (a) is oscillating globally around the center axis, (b) is oscillating the center of the left and right sides with a 180 degree phase difference. In the former case, it is expected that there will be no effect on the beam because the magnetic field located 1 mm away from the axis differs little from the central magnetic field. In the latter case, the magnetic field component perpendicular to the beam decreases due to the magnetic field tilted in the beam direction, and instead a magnetic field parallel to the beam is generated. The parallel magnetic field does not affect the beam, and the decrease in perpendicular magnetic field is about 0.5% (= 1/200, assuming that the length of the wobbler magnet is 400 mm), which is small enough to be negligible given that the distance from the wobbler to the target is within 1 m.

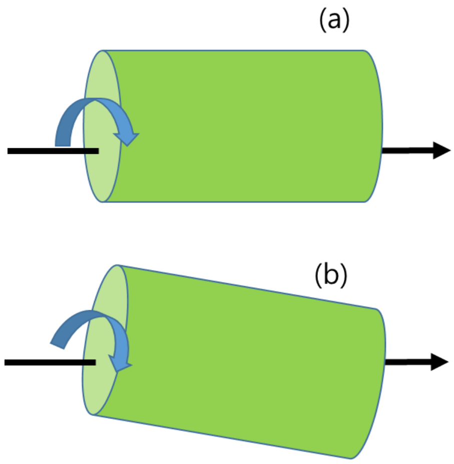

Fig. 3. Oscillation modes of the wobbler magnet

3. Conclusions and Future Plan

The beam wobbler using Halbach-type dipole permanent magnets was successfully developed. Currently, this beam wobbler is waiting for installation in the RI production target room. The disadvantage of using permanent magnets is that there is no way to stop beam deflection after installation, so it is necessary to terminate sufficient beam irradiation experiments on targets without the beam wobbler. After these experiments, the beam wobbler will be installed at the appropriate time to conduct the beam experiment.

REFERENCES

[1] Kye-Ryung Kim, et al., "Medical RI Development Plan of KOMAC", Journal of the Korean Physical Society, Vol. 71 (2017).

[2] Yong-Sub Cho, et al, “Basic Design for Wobbling System of KOMAC RI Beamline Using Halbach Dipole Magnets”, Transactions of the Korean Nuclear Society Virtual Spring Meeting July 9-10, 2020.