Journal of the Korean Physical Society, Vol. 44, No. 5, May 2004, pp. 1067∼1070

Development of a Beam Current and Position Measurement System for the Korea Multipurpose Accelerator (KOMAC)

Yong Ho JUNG,* Yong-Sup CHOI and Kyu-Sun CHUNG
Department of Nuclear Engineering, Hanyang University, Seoul 133-791

(Received 2 September 2003)

The Korea Multipurpose Accelerator Complex (KOMAC) is a proton beam accelerator (100 MeV, 20 mA) which is being constructed by Korea Atomic Energy Research Institute (KAERI). A beam measurement system composed of 4 magnetic coils was developed for the simultaneous measurement of the beam current and the position of KOMAC. In consequence of the beam measurement system experiments, the measurement range of beam current was 1 ∼ 20 mA with errors of 2.12 ∼ 3.76 %, and that of the beam position covered regions between 5 mm and 20 mm from the center of beam with errors of 2.91 ∼ 4.15 %/mm.

PACS numbers: 29.27.Fh
Keywords: Korea multipurpose accelerator complex, KOMAC, Proton beam accelerator, Beam current, Beam position, Pick-up method, Magnetic coil

I. INTRODUCTION

The Korea Multipurpose Accelerator Complex (KOMAC) is a proton beam accelerator which is being constructed by the Korea Atomic Energy Research Institute (KAERI) [1]. The proposal was to build a 2 MW (100 MeV, 20 mA) accelerator from 50 keV to 100 MeV that was to be completed in 2012 and that would be used for various applications: development of ion beam equipment for industrial purposes, conductive plastics, irradiation for power semiconductor production, explosive detection, neutron radiography, boron neutron capture therapy, functional materials, medical radioisotopes, radiation experiments of space environment, and proton therapy [1–3]. Reliable beam diagnosis is required for the development of a high-power proton beam accelerator. Especially, it is important to measure characteristics of a beam, such as current, energy, position and space distributions, *etc.* [4], in order to minimize the beam loss and to maintain beam quality for stabilized accelerator operation during the beam transport from the ion source to the last target.

The objective of this work is to develop a measurement technique for the beam current and the transverse position among the many beam parameters. The pick-up method by a magnetic coil [5] was adopted for simultaneous measurement of the beam current and the position for KOMAC not only in the initial stage of beam acceleration but also in the fully developed stage with a full range of beam currents.

A beam measurement system which measures beam current and position consists of beam current transformers [5–7], which measure the beam current (I_b) from the secondary current induced by a magnetic field through magnetic pick-up coil. Because the beam current transformer is able to measure only the beam current of 1 magnetic coil, the beam measurement system in this work includes 4 magnetic coils (up, down, right, and left coil) as shown in Fig. 1 in order to measure the beam position. Each coil has about 0.4 mH of inductance and 4 Ω

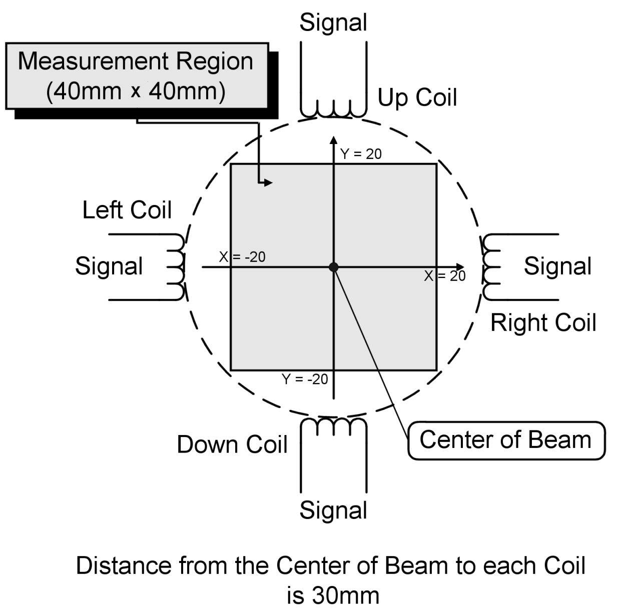

Fig. 1. Schematic diagram of beam measurement system.

*E-mail: yhjung@ihanyang.ac.kr

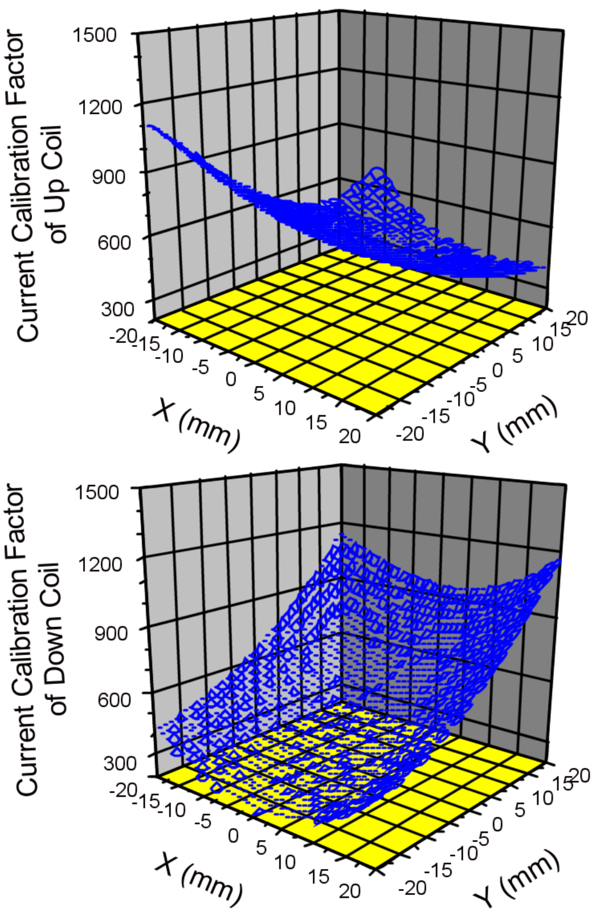

Fig. 2. Current calibration factor of up and down coil.

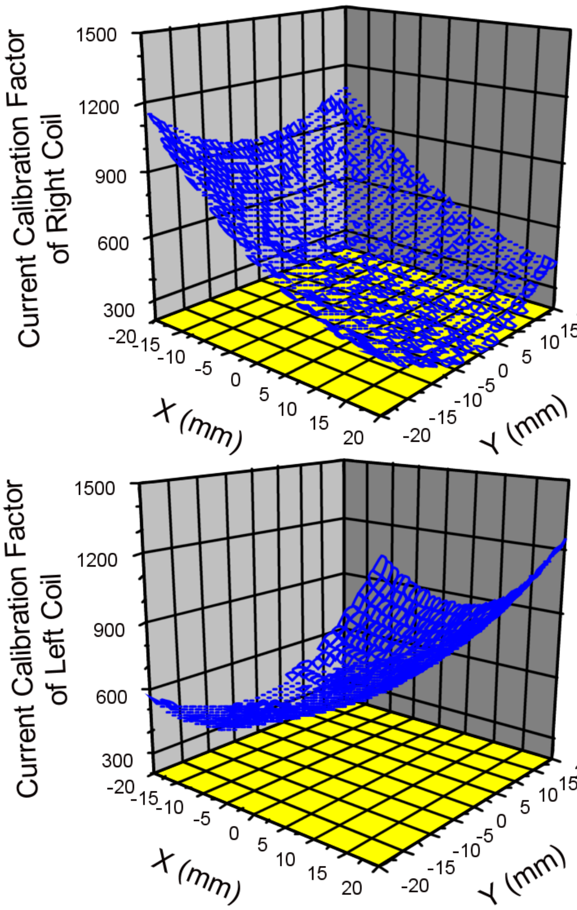

Fig. 3. Current calibration factor of right and left coil.

of resistance, and 114 turns on a cylinder with 2.9 cm of length and 0.485 cm of radius and is located at a distance of 3 cm from the center of beam. The measurement region of beam is 40 × 40 mm, the measurement distance of the beam position is 0.1 ∼ 1 mm, and the measurement range of beam current is 1 ∼ 20 mA. Because a beam current is proportional to the measured voltage signal, the real beam current is calculated from the measured voltage signals by multiplying by the current calibration factor. The beam position is calculated from the sensitivity, which is the difference in the voltage signals of two magnetic coils divided by their sum for normalization. The sensitivities can be written in two different forms, depending on the magnetic coil positions:

$$
\begin{aligned}
S_x &= \frac{V_R - V_L}{V_R + V_L}, \\
S_y &= \frac{V_U - V_D}{V_U + V_D},
\end{aligned}
\tag{1}
$$

where V is the measured voltage signal and the subscripts R, L, U, and D denote the right, left, up, and down coils, respectively.

Figures 2 and 3 show the current calibration factors of real beam currents. The current calibration factors have been shown to the range of 200 ∼ 1200. As one can see, the nearer the beam to the magnetic coil, the smaller the current calibration factor and vice versa. Figures 4 and 5 show the errors for the current calibration factor for calculation of the real beam current. It is also observed that the nearer beam to magnetic coil, the smaller the error of the current calibration factor and vice versa. This is due to the fact that measured signals are used for the beam current calculation; thus, a bigger signal gives more accurate results. Namely, measuring the beam current by using 4 magnetic coils is more accurate than measuring the beam current by using 1 magnetic coil. When a beam current is measured by using 4 magnetic coils, the average errors have been found to be 3.76 %, 3.05 %, 2.70 % and 2.12 % for the up, down, right, and left coils, respectively.

Figure 6 shows the sensitivities for positions x and y to measure beam position from Eq. (1), and Fig. 7 shows the errors for the sensitivity. The measurement region is centered at $x = y = 0$. The average sensitivity error for position x is 30.71 %/mm for the region of $|x| < 5$ mm and 4.15 %/mm for the region of $|x| > 5$ mm. The average sensitivity error for position y is 27.40 %/mm for the region of $|y| < 5$ mm and 2.91 %/mm for the

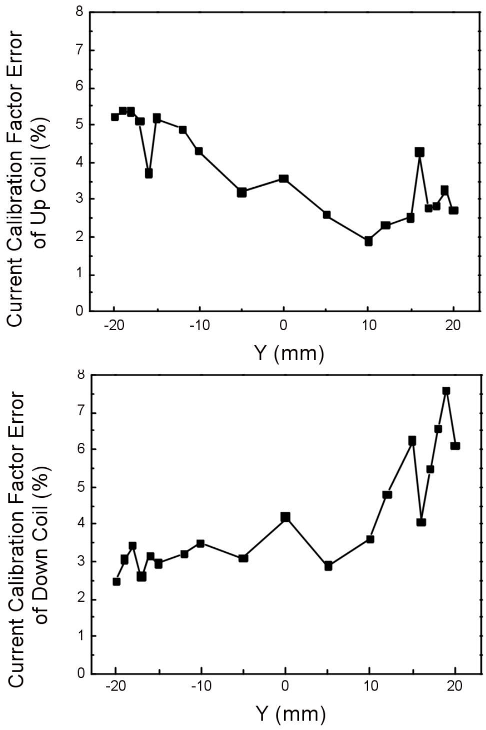

Fig. 4. Error of current calibration factor of up and down coil.

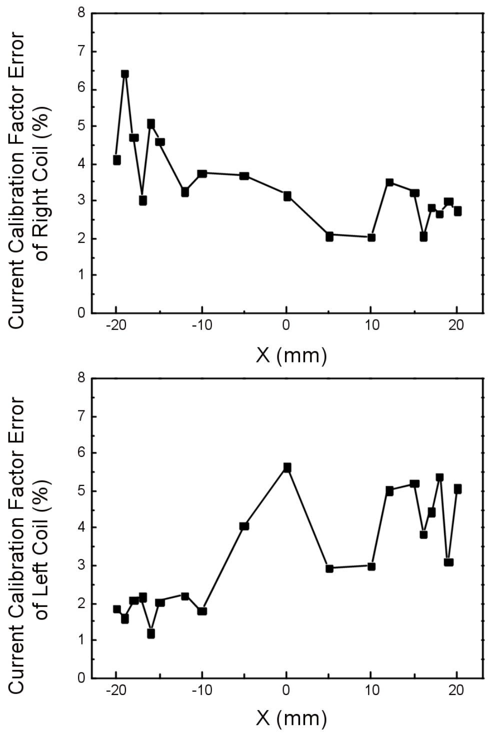

Fig. 5. Error of current calibration factor of right and left coil.

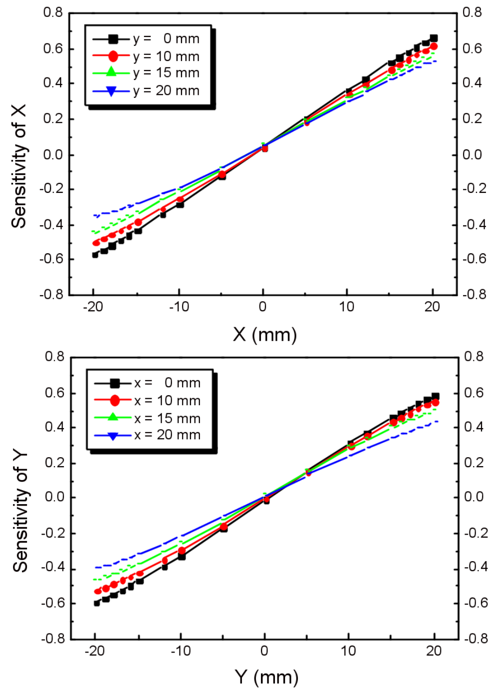

Fig. 6. Sensitivity of x and y for position transformation.

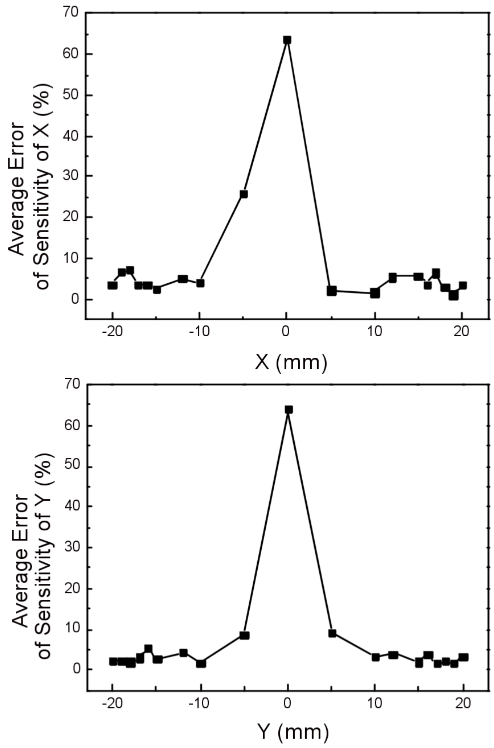

Fig. 7. Average error of sensitivity of x and y.

region of $|y| > 5$ mm. Similar to the measurement of the current calibration factor of the beam, the error is big due to the small difference in the measured signals in the region of $|x|$, $|y| < 5$ mm and is small due to the big difference in the measured signal in the region of $|x|$, $|y| > 5$ mm. Therefore, a position measurement by this system can be applied to a region between 5 mm and 20 mm from the center of the beam.

We constructed the beam measurement system for KOMAC by using a beam current transformer which consisted of 4 magnetic coils, and we applied this system to simultaneous measurement of the beam current and position for KOMAC in the initial development stage of beam acceleration. For the measurement of the beam current, the measurement range was 1 $\sim$ 20 mA and the measurement error was 2.12 $\sim$ 3.76 %. Also, when the beam position measurement was applied to the region between 5 mm and 20 mm from the center of the beam, the measurement error was found as 2.91 $\sim$ 4.15 %/mm.

ACKNOWLEDGMENTS

This work was supported by the Korea Atomic Energy Research Institute and the National Research Laboratory Project of the Korea Institute of Science and Technology Evaluation and Planning.

REFERENCES

[1] Y. S. Cho, B. H. Choi, I. S. Hong and Y. S. Hwang, Rev. Sci. Instrum. **71**, 969 (2000).
[2] J. H. Ha, Y. K. Kim, J. S. Lee, J. H. Lee, Y. S. Cho, T. Y. Song, J. M. Han, K. U. Youm and B. H. Choi, J. Korean Phys. Soc. **39**, 803 (2001).
[3] H. E. Ahn, B. H. Choi and J. H. Ha, Nucl. Instrum. Methods Phys. A **474**, 1 (2001).
[4] T. Y. Uhm, KAERI Report No. KAERI/PR-1769/96, 1997.
[5] S. L. Leonard, *Plasma Diagnostic Techniques*, edited by R. H. Huddlestone and S. L. Leonard (Academic Press, New York, 1965), Chap. 2.
[6] J. Y. Hwang (private communication).
[7] H. Koziol (private communication).