Study on the Measurement Error Factors of the Accelerator Building Alignment Network Survey at KOMAC

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1. Introduction

The 100 MeV proton linac at KOMAC (Korea Multi-purpose Accelerator Complex) has been in operation and providing accelerated proton beams to users since 2013 [1]. Highly precise alignment is required to provide proton beams with a stable and high transmission rate.

The alignment network points have been measured since 2013 for checking the alignment status.

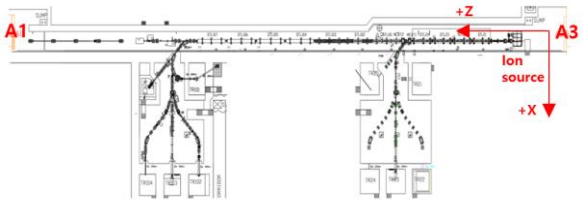

Fig. 1. Layout of Accelerator Tunnel: The A3 coordinate fixes the origin. The Z-axis can be set up by using A1 [2].

We established reference points, called the alignment network point, in the tunnel on the wall at a height of 1.8 m. Number of alignment network point is 42 in the tunnel at intervals of 10 m on the side where the +X axis (total points are 15), and were installed and at intervals of 5 m on the wall on the other side (-X axis, total points are 27).

The global coordinate system was setup by using two permanent points and the direction of gravity.

The Y axis was setup by using the direction of gravity as measured with the Leica NIVEL 210 system. The accuracy was ±0.0471 mrad. The Z axis and the origin were determined by using the two permanent references shown in Fig. 1. The A3 point located in the beginning of the tunnel was considered a fixed origin point, and A1 at the end position of the tunnel was used to determine the Z axis. These references were linked to the construction coordinate system. [2]

As a result of measurements for many years, we confirmed that there was an error in the measurement of the alignment network point comparing with the WPS monitoring result [3]. In this paper, we describe why errors occurred, and how to improve the accuracy of the alignment network survey.

We expected there are three types of error factors:

1. the station interval error
2. the laser tracker error (the angular error)
3. the lack of reference network points.

In this research, we studied to find the error factor of the first one, the station interval error.

2. Test Method

2.1 The Station Interval Error

The length of the accelerator tunnel is 135 m. The accuracy decreases as the distance increases (±10 μm +6 μm/m). The laser tracker cannot measure properly at once because of obstacles (wire, pipe, etc.). So, when we are measuring the aliment network points, we have to move the laser tracker. In this case, it is required to overlap measure points. At least 3 points for the laser tracker position should be overlapped with previous ones in order to match the position of the laser tracker [4]. We have performed this procedure almost 16 – 18 times (16 – 18 station) when measuring tunnel alignment network. We assume that errors may occur in the process of merging measured data. These errors are called the station interval error.

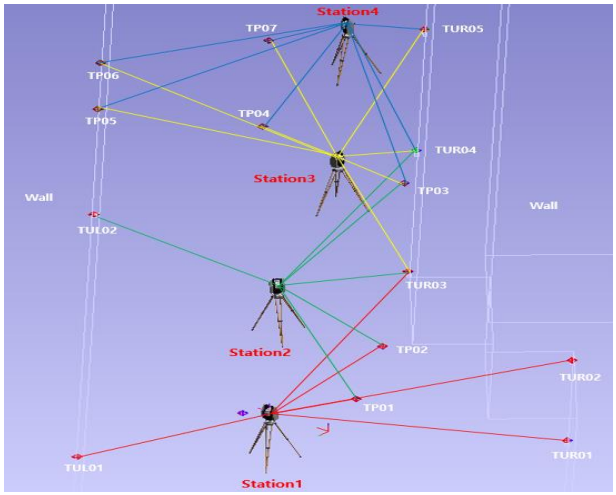

Fig. 2. Alignment Network Point Measurement

2.2 Measurement Method

We performed the measurement of the alignment network points by changing the intervals of the laser

tracker station, 12.5-m interval which corresponds to 10 different stations, 7.5-m interval; 16 stations, and 5 m interval; 23 stations. We measured just the accelerator tunnel network points.

There are 42 measurement network points in the 100 MeV linac tunnel. 15 points are on the +X side of the linac tunnel (TUL01 – 15) and 27 points are on the -X side of the linac tunnel (TUR01 – 27).

3. Results and Discussion

Figure 3 and 4 show the tendency of Y axis (vertical) measurement for TUR1 ~TUR27 and TUL1 ~TUL15 respectively.

Figure 5 and 6 show the tendency of X axis (horizontal) measurement for TUR1 ~TUR27 and TUL1 ~TUL15 respectively.

In Figure3, 4, 5 and 6 have a similar pattern, even though they are not the same value. (Value of network points are not the same. When points are installed at the same height (1.8 m) and horizontal point (X-axis) on the wall But, there is a difference of several millimeters due to the walls are not perfectly flat.)

That means it wasn't measured incorrectly and it is also not a station interval error. If it was a station interval error, the result patterns would be different. And there is an addition reason that the impact of laser tracker station interval errors will be small.

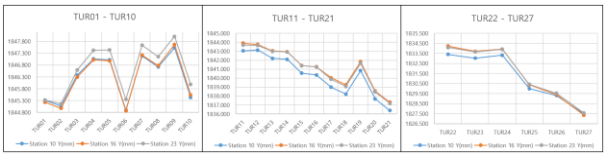

Fig. 3. Comparison of the station intervals 12.5 m, 7.5 m and 5 m (TUR01 - TUR27, Y axis)

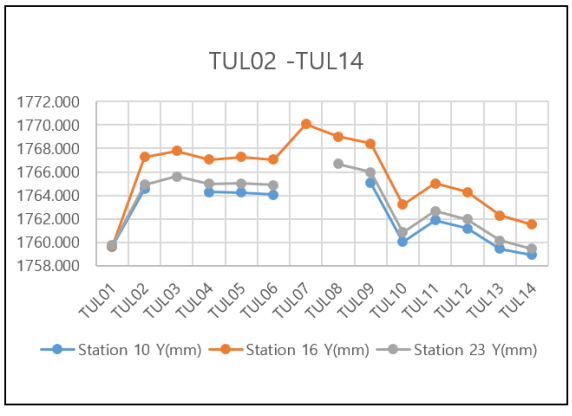

Fig. 4. Comparison of interval station 12.5 m, 7.5 m and 5 m (TUL01~TUL15, Y axis)

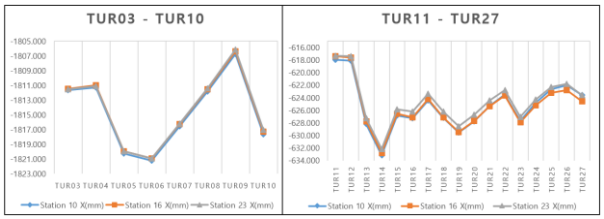

Fig. 5. Comparison of interval station 12.5 m, 7.5 m and 5 m (TUR03~TUR27, X axis)

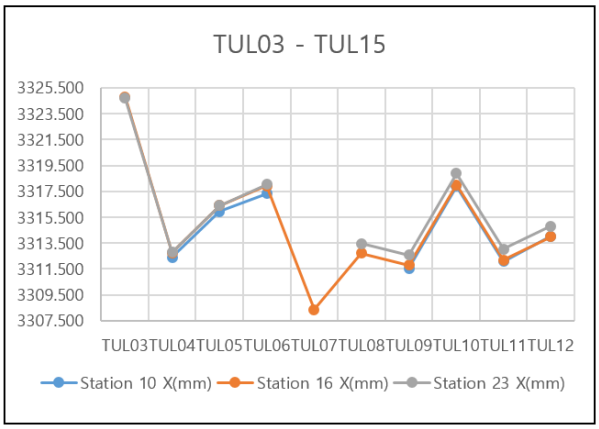

Fig. 6. Comparison of interval station 12.5 m, 7.5 m and 5 m (TUL03~TUL15, X axis)

The total length values (A3 to A1) measured by each station interval are shown in Table 1. The difference between the longest and shortest total length values is 1.517 mm. This value is smaller than X and Y compared to the total length (135 m). Only error of the laser tracker may occur approximately 1 mm. (The accuracy of a laser tracker is ±10 μm+6 μm/m.) moreover, errors due to vibration of pumps, pipes, and air conditioners inside the tunnel may be larger. But, X, Y values are more than these.

Interval(m)	12.5 m (Station 10)	7.5 m (Station 16)	5 m (Station 23)
A3 to A1(mm) [Z axis]	134794.760	134795.961	134794.444

Table 1. Measurement of the total length (A3 to A1)

If the station interval error had been applied equally to the X (horizontal, 6.4 m range) and Y (vertical, 2 m range) values, the Z (length, 135 m range) values should be significantly larger.

So, we assumed that the station interval difference is not critical more than other errors.

4. Conclusions

We conducted this measurement to find out how the laser tracker station interval affects the network point value.

As a result of the measurement, we found that the laser tracker station interval and data value had no significant effect. However, we confirmed that the errors in the horizontal (X-axis) and vertical (Y-axis) data values were larger than the longitudinal data value.

It might be errors from the laser tracker error (the angular error) or lack of reference network points. So, in the future we have to find a method of compensation to errors from measurement. For example, using theodolite and additional reference network points.

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