Short-Term Continuous monitoring of Experimental floor above tunnels of NSLS-II

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1. Introduction
2. Long term changes
3. Short term changes
4. Measurement data on March 22, 2022
5. Summary
6. Future plan
Survey result of 17 ID Straight area

1. Introduction
2. Long term changes
3. Short term changes
4. Summary
5. Future plan
1. Introduction (NSLS-II)

- East Coast of US
- New York
- Long island
- Brookhaven national lab
- EIC project (future)
1. Introduction (NSLS-II)

- 28 running beam lines
- 4 beam lines under construction
- Future update TBD
1. Introduction (Monitoring)

- Necessity of long-term monitoring (tight tolerance, slow motion every day)
- Areas covered: Linac, Booster, Storage ring, Experimental floor
- Laser tracker is used
- Measurement is done chronically (~ 3 years each round (before Covid-19)).

<table>
<thead>
<tr>
<th>Tolerances</th>
<th>Magnet to magnet</th>
<th>Girder to girder</th>
<th>Globally</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal positioning</td>
<td>± 0.030 mm</td>
<td>± 0.10 mm</td>
<td>± 3 mm</td>
</tr>
<tr>
<td>Vertical positioning</td>
<td>± 0.030 mm</td>
<td>± 0.10 mm</td>
<td>± 3 mm</td>
</tr>
<tr>
<td>Longitudinal</td>
<td>± 0.50 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roll angle</td>
<td>± 0.50 mrad</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Historical elevation changes (storage ring)

Figure 6 Historical elevation changes of storage ring monuments since Epoch 2.
Status of truck tunnel
Survey result of 17 ID Straight area

1. Introduction
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3. Short term changes
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5. Future plan
Approach

• When the access to storage ring tunnel is available, all girder fiducials and monuments in the interested area are measured with 5~7 laser tracker setups.

• Computer optimal coordinates.

• The upstream and downstream girders will be set as datum.

• The girders sitting on the top of the tunnel will be computed and recorded historically.
Long term trend in tunnel area

- The unit of the vertical axis is millimeter.
- It assumes that girder C16G6 and C17G4 doesn’t move.
- The changing magnitude is 0.7 mm horizontally and 0.4 mm vertically.
Long term trend in utility tunnel area

- The changing magnitude is 0.3 mm horizontally and 0.4 mm vertically.
- Movement is smaller but still worrisome
Summary-long term changes

• There are significant seasonal changes for the girders above both tunnels.
• It’s decided to find out the moving trend in short term.
• No long-term settlement monitoring systems such as HLS and WPS.
• Laser tracker-based setup will be employed.
Survey result of 17 ID Straight area

1. Introduction
2. Long term changes
3. Short term changes
4. Summary
5. Future plan
Ideas

• Multiple laser trackers to be used to improve accuracy (Leica AT40X, AT960 and AT901)
• Continuous measurement
• Data categorized according to time interval
• Besides the truck tunnel and utility tunnel areas, a stable area will be measured to set up a base line.
Instrument setup (on experimental floor)

- Multiple laser trackers
- Automatic measurement
Changes in 12 ID (stable area)

- The changing magnitude of both targets in X direction is about 0.01 mm, in Y and Z direction are both about 0.015 mm respectively.
- RMS deviation is 0.0020 mm in X direction, 0.0047 mm in Y direction and 0.0024 mm in Z direction respectively.
- There are 9 hours gap and a slight uptick of the data in elevation is correlated to temperature rise.

Figure 7: Outside temperature changes when measuring floor at 12 ID area.

Figure 8: Short-term changes in 12 ID area (Unit: mm).
1-hour long accuracy

- Environmental factors have very little impact in this area.
- 1-hour long duration around 8 PM is chosen from further analysis.
- 20 sets of data with three laser trackers combined.
- Combined measurement has improved accuracy.
- Better than 10 microns can be achieved with this multiple tracker measurement approach.

<table>
<thead>
<tr>
<th>Tracker</th>
<th>RMS (mm)</th>
<th>Magnitude (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DX</td>
<td>DY</td>
</tr>
<tr>
<td>ALL</td>
<td>0.0012</td>
<td>0.0015</td>
</tr>
<tr>
<td>AT960</td>
<td>0.0019</td>
<td>0.0015</td>
</tr>
<tr>
<td>AT901</td>
<td>0.0030</td>
<td>0.0024</td>
</tr>
<tr>
<td>AT401</td>
<td>0.0036</td>
<td>0.0032</td>
</tr>
</tbody>
</table>
Changes above utility tunnel (worse area)

- Suspicious changes hourly and daily.
- The amplitude is ~0.02 mm in Y direction and ~0.01 mm in X direction.
- Possible impact delay from outside temperature change.

Figure 13: Short-term changes above utility tunnel in 22 hours (unit: mm)

Figure 14: Outside temperature changes when measuring floor above utility tunnel.
Changes above truck tunnel (worst area)

- The changing magnitude of both targets in X direction is about 0.04 mm, in Y direction is about 0.06 mm and in Z direction is 0.02 mm respectively.
- The change in Y direction is the biggest and there is an apparent trend over time.
Hourly and daily changes

- There are suspicious changes in an about hourly period. The amplitude is ~0.02 mm in Y direction and ~0.01 mm in X direction.
- Besides the hourly changes, there is an amplitude of ~0.02 mm daily change in Y direction.
Short term changes summary

Table 1 Statistics of short-term floor changes in three areas

<table>
<thead>
<tr>
<th>Area</th>
<th>Magnitude (mm)</th>
<th></th>
<th>RMS (mm)</th>
<th></th>
<th>Stable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td>Y</td>
<td>Z</td>
<td>X</td>
<td>Y</td>
</tr>
<tr>
<td>12 ID</td>
<td>0.011</td>
<td>0.026</td>
<td>0.016</td>
<td>0.0020</td>
<td>0.0047</td>
</tr>
<tr>
<td>Utility tunnel</td>
<td>0.030</td>
<td>0.037</td>
<td>0.031</td>
<td>0.0041</td>
<td>0.0055</td>
</tr>
<tr>
<td>Truck tunnel</td>
<td>0.064</td>
<td>0.072</td>
<td>0.026</td>
<td>0.0119</td>
<td>0.0145</td>
</tr>
</tbody>
</table>

- Truck tunnel area is 3~5 times worser
Survey result of 17 ID Straight area

1. Introduction
2. Long term changes
3. Short term changes
4. **Summary**
5. Future plan
Summary

- A base line monitoring test in a stable area shows that a measurement accuracy of several micron can be achieved by this approach.
- The measurement of floor above utility tunnel area shows that the daily changes is relatively small but there is a trend can be found.
- The measurement of floor above truck tunnel area shows the largest change and a trend of daily change. In elevation direction, there is a suspected hourly change with the amplitude of ~0.02 mm in Y direction and ~0.01 mm in X direction.
- For all three areas, outside temperature changes show certain impact to the monitoring points.
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Future plan

- Wire positioning system is to be installed in the truck tunnel area to better understand the changes.
- Shielding measures regarding truck tunnel need be considered to attenuate the changes.
Thanks for your attention!

• Acknowledgement
The author would like to thank all the staff who involved in the NSLS-II alignment activities.

• Questions?