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Measurement of Pipe Slope with Laser Scanning Technique

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1. Introduction

U.S. Nuclear Regulatory Commission (NRC) issued Generic Letter (GL) 2008-01 which provides recommendation and guidance to nuclear power plants for managing gas intrusion and accumulation in safety systems such as Emergency Core Cooling (ECC), Decay Heat Removal (DHR) and Containment Spray (CS) systems [1]. Following the GL2008-01, Nuclear Energy Institute (NEI) reported NEI 09-10 that gives industry guidance for effective prevention and management of system gas accumulation [2]. The location of gas accumulation is usually a high point of piping systems. The high point of system is easily identified by investigating as-built isometric drawings of the subjected systems. However, the real plant piping configuration such as a slope might be different from as-built drawings. If there is a small slope on pipe which is a horizontal configuration in as-built drawing, gas can be accumulated at the high point in pipes with wrong slope as shown in Fig. 1. This paper demonstrates a feasibility to measure the slope of piping systems by using the laser scanning and presents a simple example.

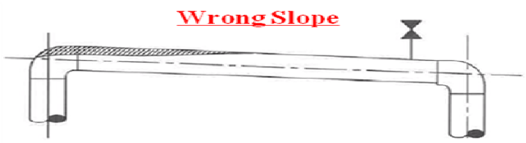

Fig. 1. Gas accumulation in pipe with wrong slope.

2. Laser Scanning

2.1 Types of Laser Scanning

Laser scanning is to measure three-dimensional coordinates for the surface of object. It is typically divided into two types. Table 1 describes types of laser scanning equipment. The broadband scanner can be used to measure the slope of pipes in safety system.

Table 1. Types of laser scanning

Type	Scanning range	Accuracy	Measurement
Broadband scanner	~10^2 m	>1mm	Time of flight, phase
Precision scanner	~10^{-2} m	<1mm	Triangulation, pattern

2.2 Post Processing to Measure Slope in Piping Systems

The measured data though laser scanning are basically point cloud that have relative three-dimensional coordinates. Thus, the post processing for the measured point data is required in order to estimate the slope of piping system. Once we have field laser scanning data, data editing is conducted to remove unnecessary data, which prevents interference in three-dimensional modeling. After completing data editing, point cloud data can be converted into mesh data which represents as-built modeling. Then, the slope of piping is estimated by creating reference plane.

3. Example

This section shows a simple example to measure slope of piping shown in Fig. 2. Laser scanner to use is Leica Geosystems Scanstation2 shown in Fig. 3. Table 2 explains specification of Scanstation2.

Fig. 2. Example of piping configuration.

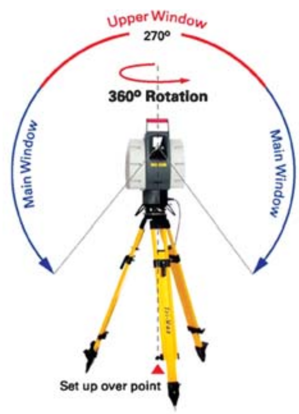

Fig. 3. Leica Geosystems Scanstation2.

Table 2. Specification of Scanstation2

Scanning type	Time of flight
Laser color	Green
Laser class	Class 3R (IEC 60825-1)
Scanning range	1m~300m
Range of 10% reflect object	Up to 100m
Laser spot size	4mm from 0~50m
Maximum resolution	1mm
Maximum scan speed	50,000 points/sec

Fig. 4 shows the post-processing for the point cloud data to estimate slope of piping. The software used in post-processing is Cyclone from Leica Geosystems and AutoCad from Autodesk. Cyclone is a special software for three-dimensional laser scanning with scanning module and modeling module.

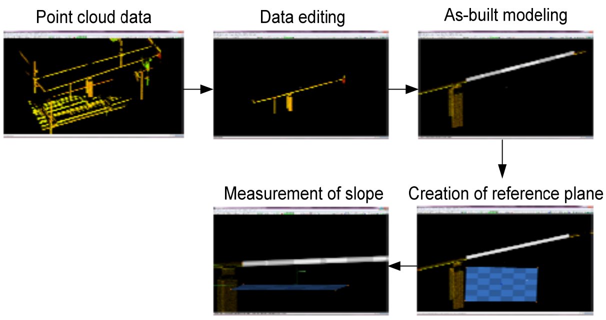

Fig. 4. Post-processing scheme.

On the other hand, the slope of piping is actually dependent upon location of measurement. To enhance the accuracy of measurement, as-built modeling is segmented with each 25cm distance starting from 5cm away from the center of the tee shown in Fig. 2. Fig. 5 shows the segmentation of the right hand side from the tee.

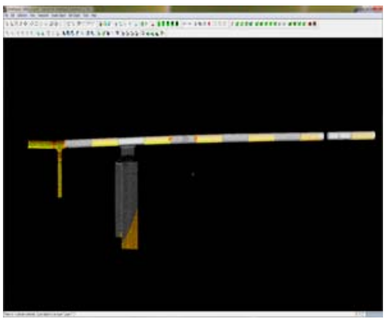

Fig. 5. Segmentation.

The slopes of piping for each segment are summarized in Table 3. The slope measurement for first segment (5~30cm) by a digital goniometer is 1.55^{o}. Therefore, the estimated slope by laser scanning with proposed post-processing scheme might have reasonable accuracy.

Table 3. Estimated slope of each segment

Distance (cm)	Slope (^{o})	Distance (cm)	Slope (^{o})
5~30	1.548	155~180	0.791
30~55	1.416	180~205	0.797
55~80	1.636	205~230	0.569
80~105	1.282	230~255	0.659
105~130	1.112	255~280	0.550
130~155	0.864	280~305	0.624

4. Conclusions

Gas accumulation in piping system impacts on the safety systems such as ECC, DHR and CS. Thus, the identification of gas accumulation location is very important. The location of gas accumulation is usually the high point of piping systems. The high point of system is easily identified by investigating as-built isometric drawings of the subjected systems. However, the real plant piping configuration such as a slope might be different from as-built drawings. In this case, the laser scanning technique can be used to identify the real high point in piping systems or wrong slope in as-built drawings. Post-processing scheme proposed in this paper shows reasonable accuracy to estimate the slope of piping. Therefore, laser scanning is useful tool to measure the configuration and slope of piping systems beyond staff's reach.

REFERENCES

[1] NRC Generic Letter 2008-01, Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems, Jan. 11th, 2008.
[2] Nuclear Energy Institute, Guidelines for Effective Prevention and Management of System Gas Accumulation, NEI 09-10 Rev.1, Dec., 2010.