Aplication of 3D Laser Scanning for Deformation Measurement on Industrial Objects

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Key words: 3D terrestrial laser scanning, deformation measurement, industrial objects

SUMMARY

Of the many facets of laser scanning application the most prominent and effective one is without a doubt the one for deformation analysis purposes. Laser scanning has provided surveyors a means to conduct comprehensive survey of objects in need of deformation analysis, thus allowing for a throughout inspection and ascertaining of all causes of deformations. In comparison to conventional survey techniques and methods this constitutes a significant progress for all professions included in this field. Not only does it make the analysis process more efficient, accurate and comprehensive but it also makes it more cost effective, as all relevant analytics can be conducted from the same data set, i.e. the point cloud.

Practical example given in this paper further substantiates those claims. The work was performed in an oil refinery on the request of construction engineers, which, by itself, is the indicator of required accuracies. When the same principles are applied to other high accuracy deformation analysis projects, one can easily ascertain the benefits of using laser scanning technology for the purposes of these types of projects.

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1. INTRODUCTION

The task at hand was to determine the extent of deformation of a heat exchanger in the Oil refinery Rijeka. This had to be done as problems had occurred during the removal of its envelope while conducting regular maintenance. It was observed that the envelope couldn't be removed easily but instead had to be shifted vertically using cranes to allow extraction without scraping the assembly residing within. Thus, concerns were raised and the question of what was the cause of this occurrence had to be answered. The most probable causes were subsidence of the tracks carrying the envelope or a vertical divergence of the heat exchangers envelopes base, i.e. the flange.

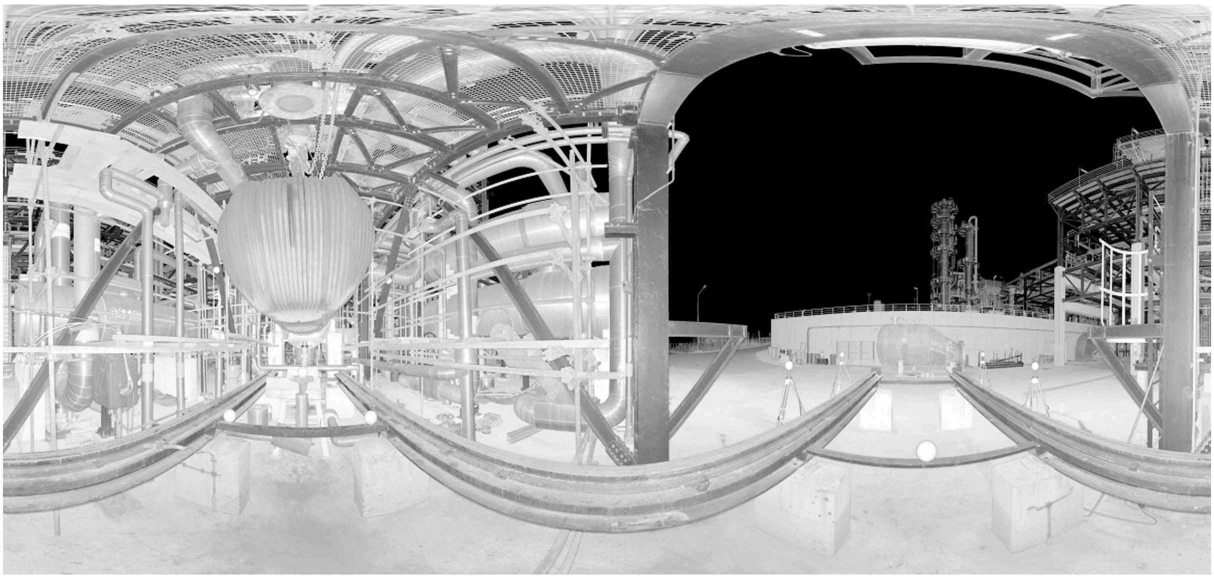

Image 1. Panoramic view of the tracks and assembly from one scan position

Now the subsidence of the tracks can be determined using even conventional surveying techniques, i.e. leveling, but the vertical divergence was judged to produce higher quality results if surveyed using laser scanning. The reasoning behind this was that as the flange that was needed to be surveyed is vertical there is no way to position a prism on its surface, so the only options available would be either to use the laser of the total station for contactless survey or to place retro reflexive stickers over the surface of the flange for electronic distance meter (EDM) measuring.
Since neither of those options seemed reliable enough for determining the anticipated mm divergence range laser scanning was the final method of choice. Another reason for opting for laser scanner in this project was the fact that the structure itself was occluded by scaffolding making it very hard to approach. Even for using the scanner the surveyors needed to be

inventive. Hence, an improvised platform was devised on site and constructed with the help of on-site workers. It consisted of a steel pipe the kind used for scaffolding and a plate bored in the centre and welded to the pipe. This was used to attach the scanner to the scaffolding from the side and above the flange thus enabling collection of data all around (Image 2.). Thus, a comprehensive survey of the flange was realized.

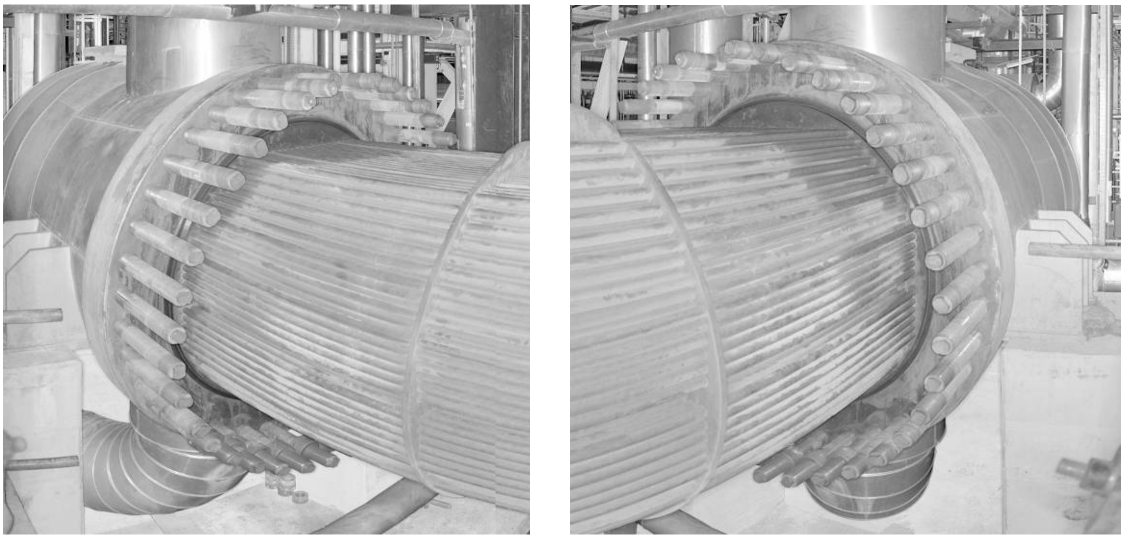

Image 2. Side views from scan positions mounted on the scaffolding

2. LASER SCANNING

Terrestrial laser 3D scanning is a survey method that utilizes laser technology when scanning the surface of an object. It analyzes a real-world or object environment to collect data on its shape and possibly its appearance (e.g. color). The collected data can then be used to construct digital, two-dimensional drawings or three-dimensional models useful for a wide variety of applications. [1].

Ground-based laser imaging is a rapid method of collecting millions of precisely sampled 3D points of objects over a range of 0.5m – 6000m. This technology is relatively new and is generating interest from various industries involved in spatial data collection and application. The ability of a laser scanning instrument to collect high-resolution data over an object or surface is an advantage over traditional surveying techniques (such as total station or GPS), especially for monitoring deforming surfaces. Global coverage is acquired rather than a sparse network of discrete points [2].

Still, laser scanning is not a replacement for existing geodetic techniques, but an alternative that can be used in most surveying work. Scanning takes place with an already well-known method of registering the distance and angle to a certain point in the recording area. The result of this survey mode is a set of three-dimensional XYZ points, which is called the point cloud [1]. Spatial distance between adjacent points within the cloud depends on the distance to the object and the technical specifications of the instrument. Most of today's scanners can capture very dense clouds of points, so it is possible to get points recorded with spatial resolution of one millimeter. The points in the point cloud are defined with their coordinates which can be in a relative or an absolute coordinate system, and also contain the information about intensity and about the RGB (Red Green Blue) color model of the reflected surface (Image 3.).

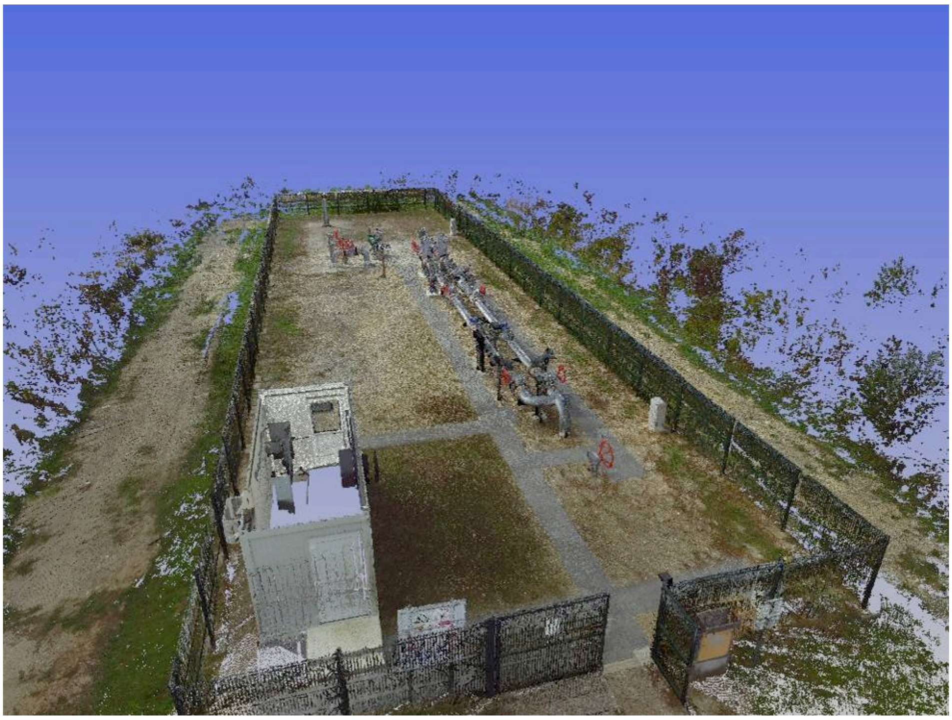

Image 3. Colored point cloud of a facility on a major pipeline

The point clouds can be quickly modeled into regular gridded or triangulated surfaces permitting local subsidence trends to be identified, which otherwise may have been missed by the traditional techniques. Additionally, signalized targets for control points are not essential in a laser scanning project, as laser scanners allow users to eliminate prisms from the survey because of their contactless measuring capability. Natural features may be identified and used to register multiple scan clouds. This precludes contact with potentially unsafe terrain [2].
In the early stages, laser scanning was short range and mainly used in the automotive and industrial design process to facilitate the Computer Aided Design (CAD) process. However, since technology keeps evolving, other potential fields are exploited. Mid range scanners were developed for the petrochemical industry. Due to the complexity of plants, which were only documented as 2D drawings, laser scanning led to the full 3D management of sites [1].
The obvious advantages of laser scanning (like contactless measuring, long range, high precision and data acquisition rate etc.) ensured a gradual adoption of this technology in other disciplines such as: cultural heritage, architecture, facility management, entertainment industry and forensics (Figure 1) [3].

3. DEFORMATION ANALYSIS

Deformation analysis requires processing of the acquired survey data, as data processing is the process of conversion of data into information. Information is data that are processed to be useful. The data then becomes the information that has meaning for the recipient, and also must affect the increasing level of knowledge of the recipient [4].
Afore mentioned purpose of the project at hand was to determine the cause of deformation on a heat exchanger in the Oil refinery Rijeka. As was already stated investigation of the tracks was conducted using leveling as a method for determining any subsidence occurrences. Alongside leveling total station survey was used for providing position of leveling surveys and connecting laser scanning data with other surveys.
As can be seen on Image 4., leveling data proved there were no significant deformations or subsidence' of the tracks. Thus, any causal effect related to the tracks was eliminated.

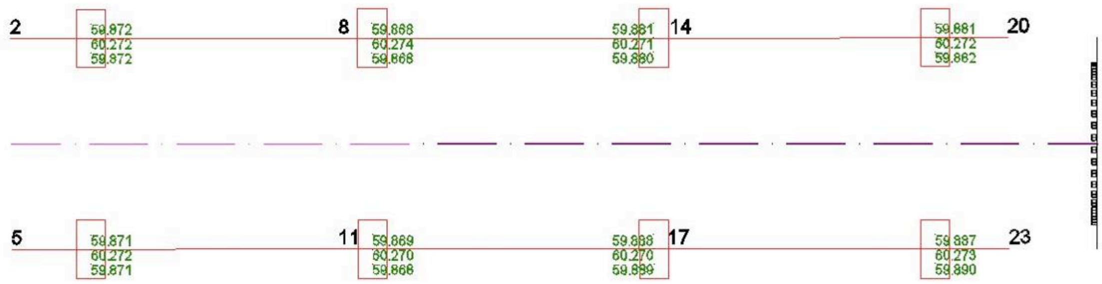

Image 4. Floor plan of tracks with leveling data values

Determining the vertical divergence of the flange was a more complex task. The main area of interest was actually the planar surface of the flange that is in direct contact with the envelope. Not only is that surface hard to access due to scaffolding surrounding the exchanger but it also has a great number of screws protruding from it. This many obstructions make it very hard to survey in a satisfactory manner using conventional methods. Thus, as mentioned previously, the survey of the flange was performed using a laser scanner.
As more than one scan position was required to capture the entire flange sphere targets were used to enable subsequent registration of the point clouds. Spheres were positioned so that a minimum of 5 spheres were visible from each scan position to ensure the best fit possible. Were it not a project with such high accuracy demands three would have been sufficient. This resulted in fitting with under millimeter accuracy.
Placing the scans into the same coordinate system as the other survey was enabled by an adapter that places a small prism in the same exact position as the sphere centre. Once those sphere center coordinates were matched to their corresponding instances in the scans the transformation process was complete.
The data was now ready for analysis. The points sampled on the flange were extracted as a separate point cloud object. It was cleaned from all superfluous data and than a plane was fitted into those points using least squares method. The result, as can be seen in Table 1., the normal vector values clearly show vertical divergence of 3,03 mm or 3 cm for every 10 meters. This finding is actually in line with problem as reported from the personnel that worked on envelope removal. To provide a more visual representation of the condition of the

flange a side view was also created (Image 5.) with some elementary information that the investor requested to be delivered.

Table 1. Geometry fitting results

	Number of points	Coordinates of the center (m)	Normal vector (m)	Standard deviation (mm)
Flange envelope Radius (1.7335)	141 957	5463269.63847; 5015873.37341; 61.70562	-0.84699; 0.53160; -0.00303	0. 49
Flange surface	269 743	5463269.54456; 5015873.43279; 61.70459	-0.84699; 0.53160; -0.00303	1.19

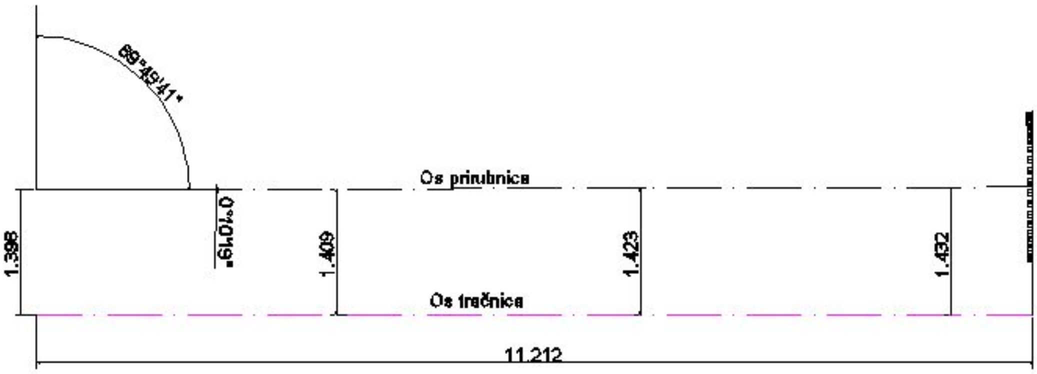

Image 5. Side view depicting the vertical divergence of the flanges connection plane

Just as a measure of precaution an analysis of coincidence between the two axes, the track axis and the flange axis, in a horizontal plane was made. It showed these two axes to be aligned within the permitted tolerances as was expected (Image 6.). The data allowing this analysis was gathered as a combination of total station survey and laser scanning survey. The axis of the tracks was constructed as a line equidistant from each track rail, and the axis of the flange as the axis of the cylinder which was also fitted into the point cloud (Table 1.).

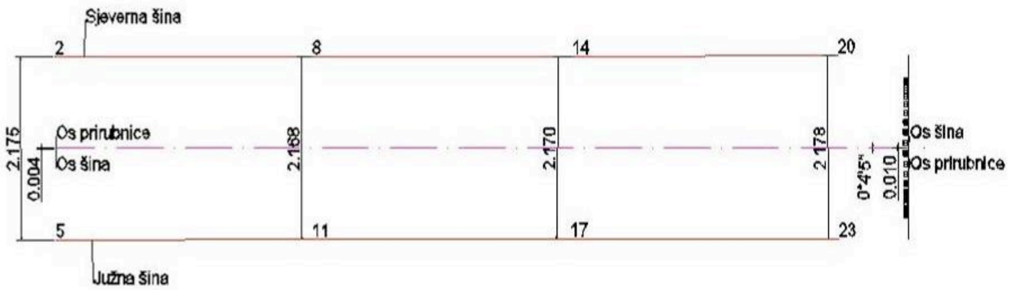

Image 6. Floor plan of tracks axis and flange axis depicting discrepancies between the two

4. CONCLUSION

Terrestrial laser 3D scanning is one of the most promising contactless measurement technologies. It allows acquisition of a large amount of precisely measured points in a very short period of time [3]. Growing interest for this technology comes from a number of professions that deal with spatial information and visualization. It also found its application in civil engineering [5].
In this specific project it proved as a valuable asset without which it would have been very hard if not impossible to obtain data of adequate value for deriving sound conclusions. Laser scanning originated from automotive and petrochemical industry so it is not illogical for its usefulness to over and again show such potential exactly in these areas. Whether it be for documentation of complex facilities or deformation analysis the basic requirement is the same: to have the ability to collect comprehensive, detailed and accurate data that can ensure deriving relevant conclusions and produce valuable information.

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BIOGRAPHICAL NOTES

Luka Babić: Working on the University of Zagreb, Faculty of Geodesy since 2008. Main area of interest is laser scanning in all fields of application. Worked on a variety of laser scanning projects including industrial, mining, infrastructure, cultural heritage and urban planning projects. His latest focus are BIM processes and surveyors role in those processes.

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