

Measurements of geometry of a boiler drum by Time-of-Flight laser scanning.

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Abstract- In the paper the application of ToF laser scanner in measurements of geometrical parameters of a boiler drum in power plant is presented. The point clouds acquired by the scanner have been subjected to a set of post-processing operations that provided the most important geometrical parameters of the drum. The obtained data can be used for optimization of the process of mounting a mechanical steam-water separation during renovation works. Currently used separations are tightly placed in boiler drum, so the welding process is not required anymore. This approach saves the time of renovation works, but the geometry of a separation has to be precisely matched against the geometry of the drum to ensure the tightness of connection and, in consequence, to ensure stability of steam parameters (pressure and temperature).

I. Introduction

The power generating industry is one of the most vital branches of the economy. In order to ensure safe operation of installations for many years, full-time monitoring and diagnostic tests are carried out, in order to plan a schedule of overhauls. The lack of adequate maintenance procedures can be a threat for employees and local population and also can cause huge financial losses due to a risk of failures of industrial installations. Currently in most cases monitoring of installations in heat and power generating industries is carried out with utilization of standard pointwise sensors [1, 2]. However, due to many unresolved problems, there is still a need to search for alternative techniques for both monitoring and measurement/diagnostic tasks, which could be more accurate, relatively cheaper, and could provide more useful data.

In recent years it has been shown that optical measurement techniques may play an important role in maintenance of installations in heat and power generating industry. In [3] the Digital Image Correlation (DIC) method [4] and structured light method [5] have been utilized for displacement and shape measurements of pipelines during start-up. In [6] DIC and thermography have been used for diagnostics of expansion bellows in district heating pipelines. In many cases it is also required to monitor displacements of pipelines in large volume [7]. Although all mentioned applications proved feasibility of the utilized methods and solved certain engineering problems in heat and power generating industry, for some particular tasks other methods are better suited. This especially concerns the tasks, in which whole geometry of large objects needs to be determined in a limited time (displacements and strains are not important). An example of such case is preparation of technical documentation of a boiler drum during repairs.

During repair process of boiler drums, separations are replaced with new ones, which have to be tightly mounted. The crucial step in mounting of the new separation is to ensure it fits to the actual geometry of the drum. If this condition is not met, resulting leakages may cause issues with maintenance of operational parameters of steam (such as temperature and pressure). Precisely described geometry of the boiler drum would significantly facilitate this step, thus save the time of the process.

Currently technical documentations of boiler drums include the data acquired by surveying. Typically the radius of a boiler drum is measured in 8 points in each segment. The geometry of the boiler drum is described by data merged from all segments. A set of pointwise measurements, however, would not be enough to determine geometrical parameters such as: cylindricity deviation or segments misalignment. In the presented works, the ToF laser scanner has been used for geometry measurements of a boiler drum. Post-processing analysis have been carried out subsequently in order to determine geometrical parameters of the drum.

II. Methodology

The measurements of geometry of a boiler drum have been carried out in a power plant in Poland. The drum consisted of 7 segments and 2 boiler ends (Figure 1a). The nominal diameter of the measured drum was 1600mm and its length was 16m (without boiler ends). The measurement method and the scope of measurements have been carefully planned with technicians from the power plant.

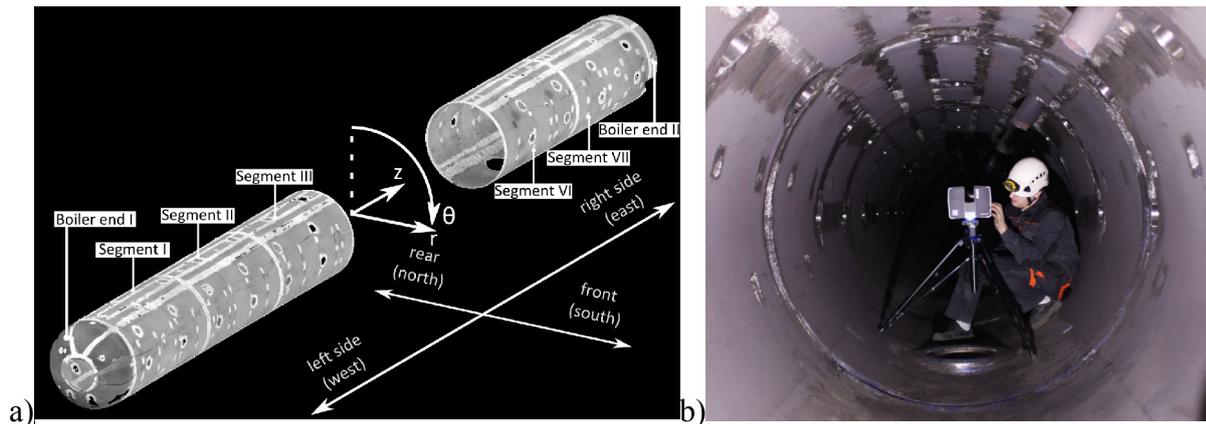


Figure 1 a) Point cloud of the measured boiler drum in the cylindrical coordinate system, b) ToF laser scanner during the measurements in the boiler drum.

A. Measurement method

The measurements have been carried out with Focus 3D S 120 ToF laser scanner manufactured by FARO [8]. ToF is a device that uses laser light to probe the subject. At the heart of the scanner is a time-of-flight laser rangefinder, which only detects the distance of one point in its direction of view. In order to scan the entire field of view, the range finder's direction is changed. The scanner needs to be calibrated in laboratory in stable conditions before the measurements start. Results from ToF scanning are point clouds representing the geometry of the measured object. The nominal speed of measurements with the particular scanner, that has been used in the measurements, is 976 000 points per second. The nominal range is 0.6m÷330m and accuracy is ±2mm.

The minimum operating range of the scanner was 0.6m and the nominal radius of the drum was 0.8m. In order to ensure good accuracy of measurements, the scanner had to be carefully placed in the centre of the boiler drum (see Figure 1b). Another problem was the length of the drum (approximately 16m without boiler ends). The best measurement accuracy with ToF scanner can be achieved when the sampling beam is perpendicular to the measured surface. If this condition is not met, the basic accuracy can be decreased. In order to maintain good accuracy along the entire drum, each segment has been scanned separately together with both boiler ends and spherical markers fixed to the boiler ends. Boiler ends of the drum were visible in each measurement because the drum was empty during the measurements. The point clouds of boiler ends have been consequently used in order to merge point clouds representing each segment into one point cloud. The obtained result was deviated due to difficult environmental conditions. Thus, in the next step, the obtained point cloud was subjected to noise reduction algorithms such as: 1-D median filtering and zero-phase digital filtering.

B. Scope of research

The goal of the measurements was to determine geometrical parameters of the boiler drum. The most important parameters are:

- cylindricity deviation over the entire length of the drum,
- deflection for individual segments,
- vertical and horizontal deflections along the drum,
- deviation of alignment between sectors of the drum.

All listed parameters were determined by analysis of the point cloud obtained from the measurements. In order to facilitate calculations, in the first step all data have been transformed into cylindrical coordinate system. The obtained point cloud and the orientation of the coordinate system are presented in Figure 1a.

III. Measurement results

In the first step, a cylinder has been fitted to the obtained point cloud with utilization of iterative sum of square differences algorithms. The axis of the fitted cylinder has been selected as the axis of the new, cylindrical coordinate system.

A. Cylindricity deviation over the entire length of the drum

In order to determine the cylindricity deviation over the entire length of the drum, local radius of the drum has been calculated in each point of the cloud. The results are presented in Figure 2. In order to facilitate interpretation, the results are visualised as a cylindrical surface mapped onto a plane.

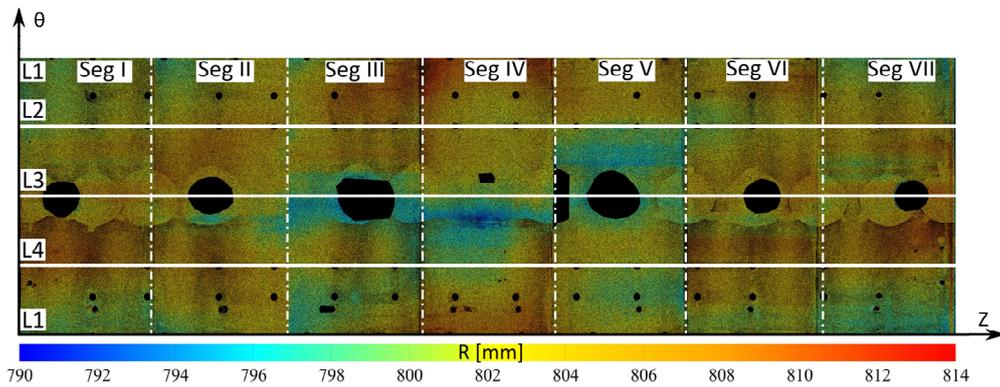


Figure 2 Radius map of the measured drum after mapping a cylindrical surface onto a plane, with overlaid lines of further analysis.

The range of calculated radiuses of the drum was $794\text{mm} \div 810\text{mm}$. The discrepancy between minimum and maximum radius was 14mm , which indicates correctness of exploitation and previous repairs. Previous works did not influence significantly the geometry of the drum.

B. Vertical and horizontal deflections along the drum

In order to determine vertical and horizontal deflections along the drum, the obtained point cloud has been cut by two planes (see figure 3). Intersections of the planes and the point cloud have been labelled as L1, L2, L3 and L4 lines.

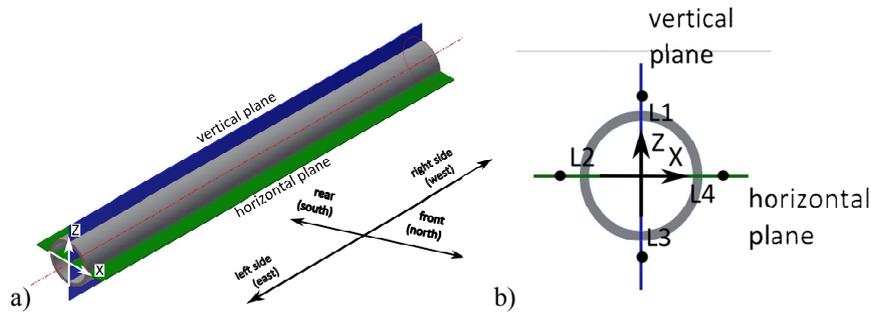


Figure 3a), Visualisation of intersection of the drum with the planes **b)** view from the front of the drum.

Deflections for each segment have been calculated as the maximum difference between the nominal radius and the measured local radii. An example surface profile determined along the line L1 is presented in Figure 4. Results for all segments and entire drum are presented in Table 1.

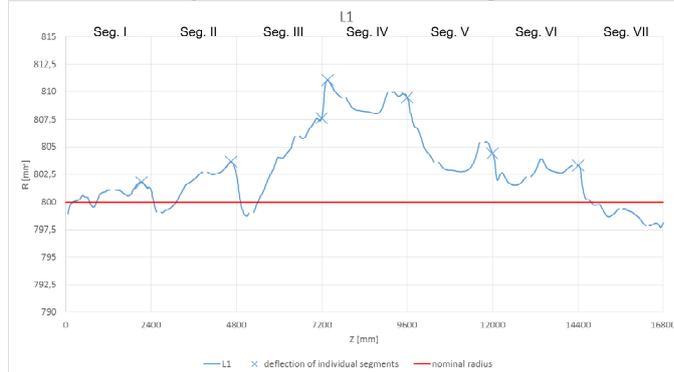


Figure 4 Radius of the drum determined along the line L1, with marked deflections for individual segments.

Table 1. Deflections along lines L1, L2 L3 and L4 for each segment and for the entire drum (maximum).

Line	Deflection [mm] in segment							Max.
	I	II	III	IV	V	VI	VII	
L1	2	4	8	11	9	4	3	11
L2	3	6	6	6	3	4	5	6
L3	7	5	-2	2	-2	6	7	7
L4	8	7	3	7	6	6	6	8

Values of deflections did not exceed 11mm . Taking into account the length of the drum (approximately 16m), the values of deflections were negligibly small. In the next step, by adding radii along lines L1, L3 and L2, L4, vertical and horizontal diameters have been calculated. The largest deviation from the nominal diameter was 12mm . The biggest differences between diameters of neighbouring segments (particularly between sectors 3 and 4) was 14mm . Separation between these two segments has been mounted with special care.

C. Deviation of alignment between sectors of the drum

In order to calculate deviation of alignment between sectors of the drum, the point cloud has been cut by planes $\pi_1 \div \pi_6$ perpendicularly to the axis of the drum (Figure 5a). Deviations have been calculated as a distance between intersection points of the planes $\pi_1 \div \pi_6$ and axes of each segment of the drum (Figure 5c and 5b). The results are presented in Table 2.

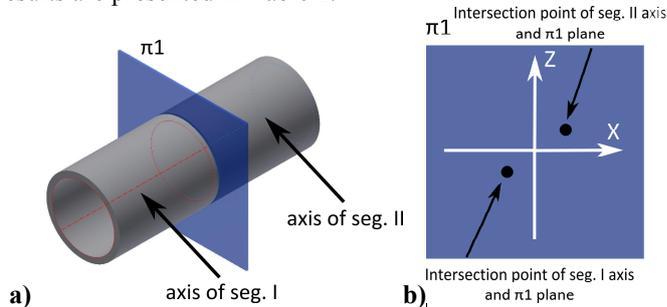


Figure 5 Visualization of the procedure for calculation of the alignment deviation: a) cutting planes and the drum, b) intersection points of the plane and the axis of the section of the drum.

Table 2. Deviations of alignment between sectors of the drum.

Plane	Misalignment [mm]
π_1	3
π_2	3
π_3	6
π_4	5
π_5	0
π_6	5

Maximum misalignment between sectors of the drum was *6mm*. Taking into account the length of the drum (approximately *16m*) this value is negligibly small.

IV. Conclusions

The most important geometrical parameters of the boiler drum have been determined from the point cloud acquired with a ToF scanner. All measurements were carried out in-situ and took about 3 hours. The amount of useful data obtained from the measurements can be used to optimize the works connected with renovation of the boiler drum. This especially concerns the process of mounting the mechanical steam-water separation. Presented measurement methodology has been accepted by experts from the industry and can be used as a good alternative to the currently used pointwise techniques.

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