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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 used in a power plant is presented. These parameters are required during renovation works, for verification of correctness of annealing process and optimization of the process of mounting a mechanical steam–water separation. The currently used separations are tightly placed in a boiler drum, so a 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). Renovation works may include heating processes, after which geometry should also be carefully verified as improperly performed can lead to buckling of a boiler drum. In the presented approach ToF scanner provides cloud of points, which has been subjected to a set of post-processing operations including stitching, cylinder fitting, projection 3D data onto 2D map, 2D data interpolation and filtering. As the result, the required dimensions and tolerances are obtained and are ready for further implementation.

1. Introduction

Power generation 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, and the resulting data is used while planning overhauls schedule. Lack of adequate maintenance procedures can be a threat to employees as well as to local population and may also cause huge financial losses due to a risk of failures of industrial installations. Currently in most cases monitoring of installations in heat and power generation industry 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.

Recently it has been shown that optical measurement techniques may play an important role in maintenance of installations in heat and power generation 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

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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 generation industry, for some particular tasks other methods are better suited. This especially includes 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 a case is preparation of technical documentation of a boiler drum [8] during repairs.

During renovation works, which include material renewal, holes with material defects are reamed, and removed material is overlaid by welding. After this process whole structure is subjected to the annealing process, in order to ensure material relaxation. Annealing process is performed with the use of eddy-current heating. Due to the length of the structure (16 m without boiler ends), incorrectly performed process of heating will result in buckling. Therefore the geometry should be carefully verified.

During repair process of boiler drums, separations are replaced with new ones, which have to be tightly mounted. The crucial step in mounting 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 saving 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. Therefore the full field 3D geometry measurements have been performed. In power plant the environment is dusty and the accessibility of boiler drum is limited (diameter of input hatch was 0.8 m). Considering this, the three shape scanning methods have been taken into account: measurement arm with triangulation based 3D laser scanner (LS) [9,10], structured-light (SL) 3D scanner [5], time-of-flight (ToF) laser scanner [11–15]. First two methods give higher resolution compared to ToF method, but the limited size of the measurement field would result in a significant increase of the measurement time. Apart from that, large dimensions and limited measurement field imply multiple measurements and stitching together resulting point clouds (PCs) that correspond to individual measurements in order to calculate geometrical parameters of the subject being analyzed as a whole. Smaller field of view in the case of LS and SL methods would result in a significant increase in the number of PCs that need to be stitched together when compared to ToF method. This in turn means that longer processing time would be required and lower accuracy could be achieved since every stitching operation introduces some error. Moreover, a ToF scanner is capable of performing measurements from greater distance, which allows capturing markers and fixed surfaces on opposite ends of the boiler drum during each measurement, and therefore propagation of error connected with PC stitching can be minimalized even further, in contrast to LS and DL methods.

During renovation works the reduction of time is an important issue since installation downtimes cause financial losses, and thus the work described in the paper has been performed with the ToF scanner. Also due to proper selection of ToF parameters and measurement conditions and extensive PC post-processing procedures based on custom-built software we were able to determine geometrical parameters of the drum with sufficient accuracy. In the paper we present at first the measurement methodology and data processing technology chain (Section 2). Then the results of measurement and data processing are reported in Section 3 including: determination of cylindricity deviation over the entire length of the drum, Vertical and horizontal deflections along the drum, coaxiality of the drum. Finally, in Section 4, we discuss the practicality of the proposed tools and methodology as well as their acceptance by power generation industry.

2. 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 (Fig. 1a). The nominal diameter of the measured drum was 1600 mm and its length was 16 m (without boiler ends). The measurement method and the scope of measurements had been carefully planned with power plant technicians.

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

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

All listed parameters have been determined by means of the analysis of the point cloud obtained from the measurements. In order to facilitate calculations, the data has been analyzed in cylindrical coordinate system. The obtained point cloud and the orientation of the coordinate system are presented in Fig. 1a.

2.1. Measurements

The measurements have been carried out with Focus 3D S 120 ToF laser scanner manufactured by FARO [16]. 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