New Tools for the Monitoring of Cooling Towers

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ABSTRACT

Cooling towers are essential for the performance and availability of industrial production units. Always higher, they are made up of a fine and light reinforced concrete shell. Their preventive and predictive maintenance is necessary to extend their lifespan but their accessibility remains difficult. Issued directly from SITES 25- year experience in the implementation of remote methods of investigation based on the follow-up of visual and dimensional defects on these structures, SCANSITES 3D® is now the tool of reference for the diagnosis, follow-up and monitoring of cooling tower using current technologies.

INTRODUCTION

Cooling towers achieve the cooling function in most of industrial and nuclear facilities. The collapse of such structure is not allowed due to its importance in terms of its economic and emblematic position. In this way and regarding its size and constitution which are exceptional, structural health of cooling towers need to be monitored in order to avoid heavy and expensive repairs if done too late and with methods which do not require shutdown of the facility.

Since decades, among the existing monitoring devices and methodologies applied to the shell, two are widely used for large structures safety management: visual inspection and geometric survey. The first is usually carried out with empiric methods, and the second is realized using accurate but discrete methods such as geodetic micro-triangulation.

This paper introduces a new approach, using an exhaustive and numeric method called " SCANSITES 3D® ".

The SCANSITES 3D® is based on the combination of the SCANSITES® method, an advanced tool which provides numeric defects inspection on large structures, a new wide ranged LIDAR technologies aiming to deliver geometric exhaustive mapping, and photogrammetric coverage.

In the first part of this paper, we will introduce the SCANSITES® method, in a second part the LIDAR coverage and in the third one, the photogrammetry. We will explain how the combination is performed and which data can be extracted on large structures. Before concluding, we will extend this paper with additional data which could be overlaid, such as thermographic pictures.

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SCANSITES® OVERVIEW

Due to the low thickness of the shell, the knowledge of its cracking and evolution is necessary for monitoring.

In the past, many owners weren't completely satisfied with the traditional defects mapping process, using binoculars or rope access. The main drawback is the difficulty to produce a scaled defects map enabling an accurate and reproducible monitoring (crack evolution, opening measurement…). To answer this problem, the SCANSITES® was developed in 1990's. This system aims to produce a numeric defects mapping connected to a database which is working as a true real-time G.I.S. (Geographic Information System) (Figures 1, 2 and 3 below). It is composed of:

An hardware tool with a robotized inspection head and its controllers,

A software suite including a database and several dedicated inspection tools (defects localization, cracks opening measurement, geometric and pathological characteristics…).

The whole system is designed to operate in-field, without heavy carriage. Several dozens of cooling towers have been surveyed by the SCANSITES®, in France and across the world, by SITES Company team.

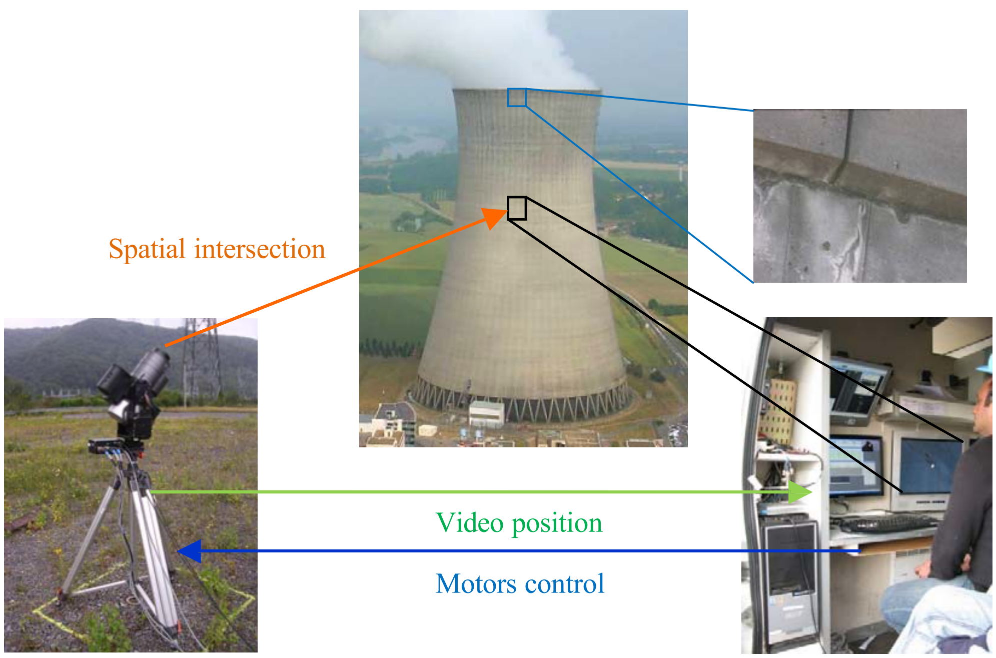

Figure 1. SCANSITES® in operation.

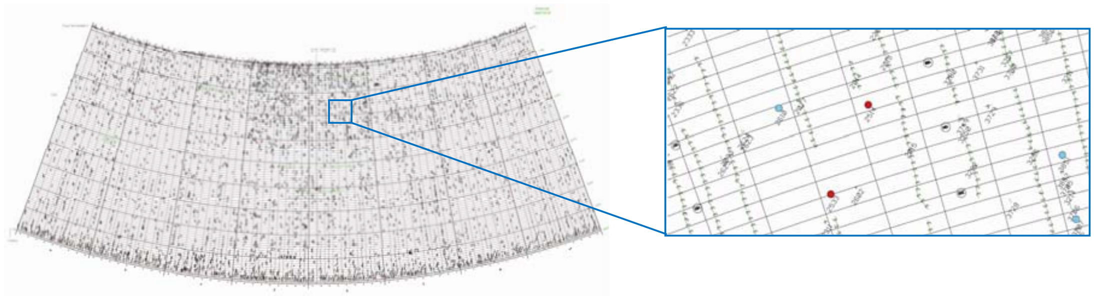

Figure 2. Defects mapping (conical projection).

Figure 3. Picture of a defect captured with SCANSITES®.

LIDAR OVERVIEW

The LIDAR (Figure 4) is a device which aims to produce some high density surveying in 3D coordinates. It's based on two angular coders and a remote electronic distance measurement device. The system works with enough velocity to acquire more than 100 000 points each second. For the majority of cooling towers, a wide range LIDAR is used. It is able to scan structures, up to 1000 meters onto surfaces.

The result of a LIDAR survey, called "point cloud" (Figure 5), is usually composed of tens of million points known in XYZ. The average density is 1 point each 5 to 20 mm and the accuracy of the modelling surface is few millimeters (5-10mm).

Figure 4. LIDAR in operation on a survey pillar.

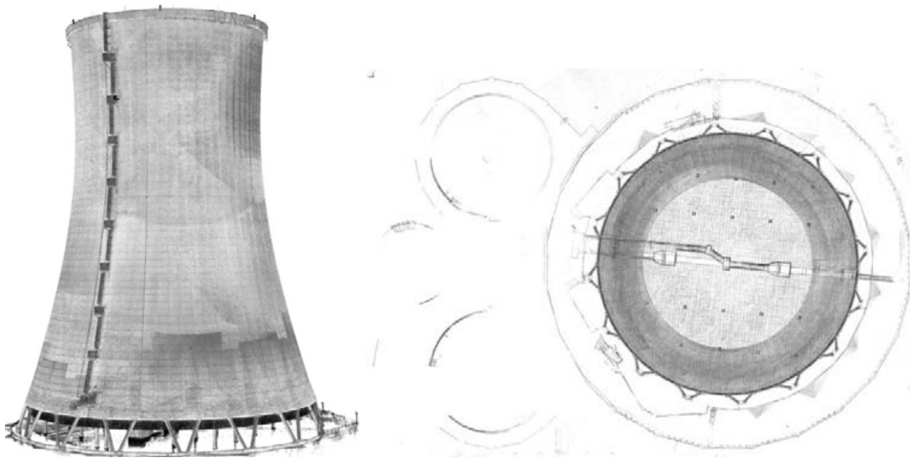

Figure 5. Point cloud of a cooling tower - intensity colored (perspective view and top view).

HIGH DEFINITION ORTHOPHOTOGRAPHIC COVERAGE

In this case, the photogrammetric coverage aims to deliver exhaustive and high definition pictures of the structure. The goal is to be able to produce a visual inspection, using 3D referenced pictures. The camera and lenses used can give a pixel equivalent to few millimeters onto the structure, which makes it possible to detect the main defects. As the photos orientation is known, each photo can be projected on 3D mesh to texture it (Figure 6). Next step is to project the textured 3D mesh on a primitive projection (plane, cone, cylinder) to obtain a map. This projected image is called orthophotography.

Figure 6. High accuracy picture of degradation captured with the camera.

OPERATIONS

In this section, we will explain the different steps required to produce a SCANSITES 3D® survey. As previously mentioned, all data are known in 3D referential. For that, the method can use the one established for the traditional survey (targets, pillars). In case where there is no available network, it is necessary to create one, based on singular points on the structure and determined with traditional survey operations.

Regarding the visual inspection, each cooling tower owner has its own requirements. It deals with defects, which have to be surveyed, and the associated classification. One of the most important parameter is the minimum opening for a crack that needs to be surveyed. It mainly impacts the focal length used during the inspection (up to 4000 millimeters!) and widely, the total number of defects stored. All those considerations help to prepare the mission, mainly the database and the inspection software.

At this step, in-field operation can begin.

SCANSITES® and LIDAR are set at different locations in order to cover the structure's surface. The high gain video camera and quality lenses of the SCANSITES® allow it to work with low ambient luminosity. The LIDAR, for its part, can work without light.

With the LIDAR, a complete scan is realized. Based on this point cloud, a triangular meshing (Figure 7) is generated and converted in a 3D shape. The first use of this 3D shape is to allow the SCANSITES® to locate the defects in 3D.

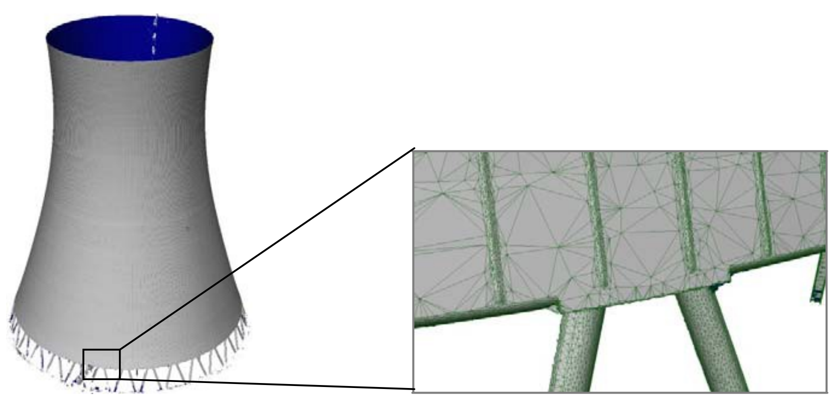

Figure 7. Triangular meshing.

With those incoming data, we proceed to the visual inspection. The operator inspects the entire shell by moving the inspection head with a joystick. When a defect is seen, it is caught. The 3D map is updated in real time with defects and the database is filled in, with its characteristics and coordinates (Figure 8).

In parallel to the scanning operation, a complete high definition photogrammetric coverage is done.

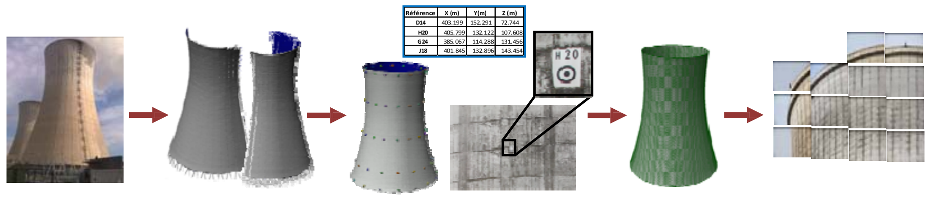

Figure 8. Block diagram of operations.

TREATMENTS

The treatments aim to produce, on a multilayer file, a map containing all defects caught, the geometric deflections and the photogrammetric coverage.

The first step is to compare the tower's 3D shape to the theoretical shape or to a previous survey. The 3D deflections are extracted and a map is generated. Two ways of representation are possible. One is a coloured map: each colour depending on deflection value. The other way is to carry out a contour line representation.

The second step is to overlay the defects surveyed with the SCANSITES®, using the referential network.

The last step is to overlay the pictures directly on the structure's 3D shape enabling to produce an orthophotography. With that file, many views can be generated such as composite views: defects/deflections, defects/pictures, or thematic views (based on database queries).

Case study: cooling tower n°1

The SCANSITES 3D® method was applied on a cooling tower, located in France. Its main figures are 120 meters height and 80 meters diameter at the bottom. The average distance between SCANSITES 3D® points of view and the downstream facing was about 150 meters. The aim of this job was to connect the geometric deflections to the defects surveyed.

The LIDAR survey recorded 30 million points, and the defects total quantity was near 4000.

The map (Figure 9) shows a colored layer of the shell deflections to theorical shape vs. defects drawing (mainly cracks, repaired defects and corrosions).

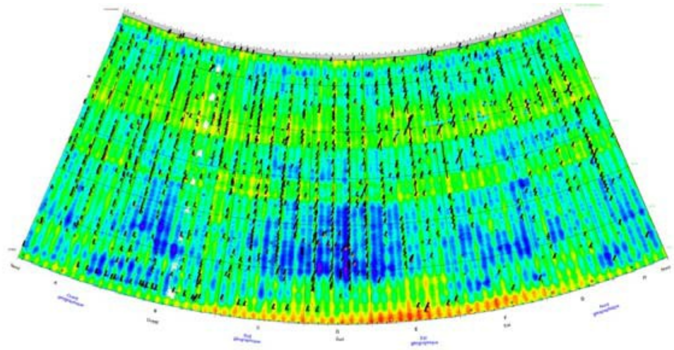

Figure 9. Map overlaying deflection/defects and magnifying.

Case study: cooling tower n°2

The second case study concerns a cooling tower located in Europe but slightly smaller: 90 meters height and 50 meters diameter at the bottom.

The aim of the job is to get tower geometric deflection, a very accurate visual inspection onto the sensitive part, a less detailed inspection onto the common part and a global photogrammetric coverage (Figure 10).

As carried out on the previous case study (Cooling tower n°1), a LIDAR point cloud was generated representing 25 million points. In parallel, we covered the whole shell with high resolution pictures, projected it on 3D shape, and then on projection cone, for a total quantity exceeding 1 billion pixels.

Concerning the visual inspection, the SCANSITES® was used for the sensitive part. For the common part, all defects were caught directly on the 3D textured model.

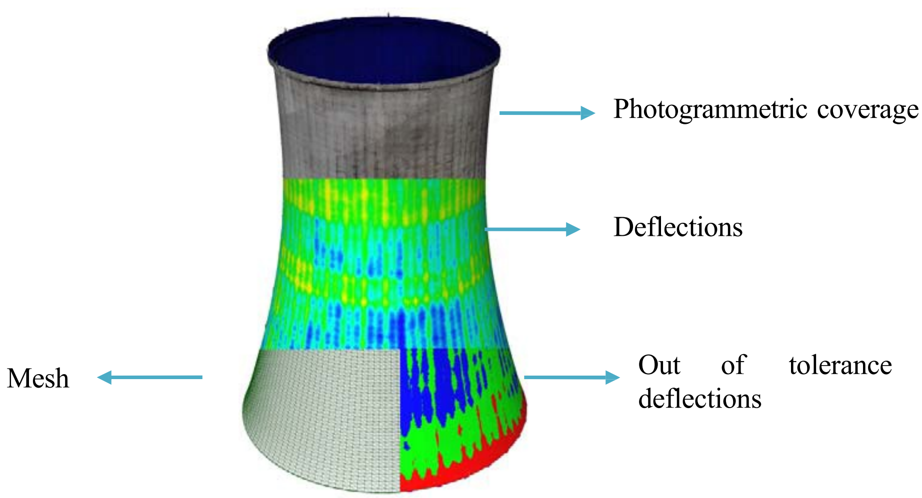

Figure 10. Representation of 3D model, deflections and photogrammetric coverage.

RESULTS

Concerning the visual inspection, the traditional way is to produce a sketch based on a close inspection (rope access) or binocular observations. The consequent difficulties of those methods are to get a good location of the defects and their evolution. SCANSITES 3D® provides some numerical results: a scaled defect map and defects database. The first result is to produce an accurate report emphasizes defects evolution between two inspections, and the number of defects classified by zone (Figure 11). This is helpful for establishing an accurate bill of quantities for restoration works, like total crack length to be treated, total corroded bar amount for passivation treatment…

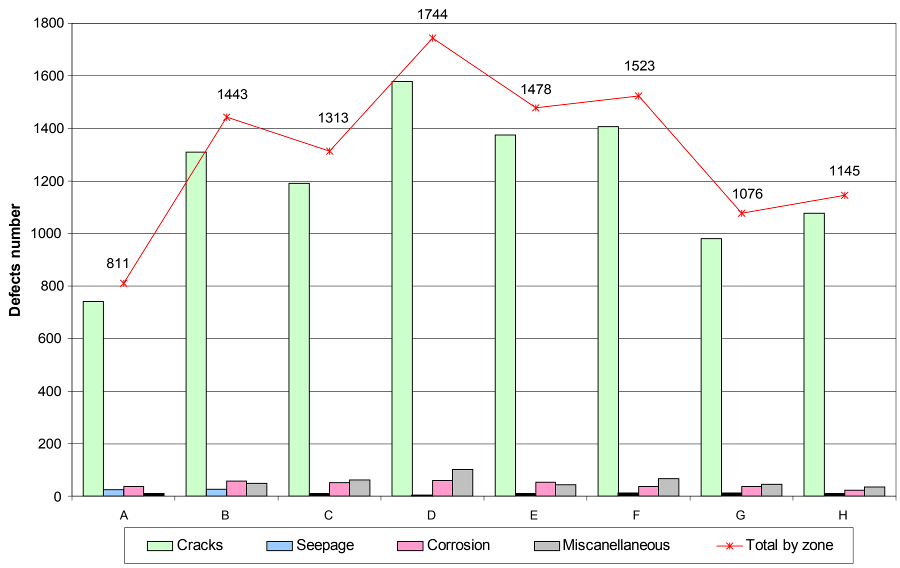

Figure 11. Number of defects by family and zone.

The LIDAR coverage is a guideline for defects analysis, for instance to see if cracks are correlated, or not, with geometrical distortions.

Another interesting point is its use on parts covered of vegetal moss. Scanning one way we get structural information whereas visual inspection is inefficient. It is also helpful to know where a structural diagnosis has to focus on (with concrete sample or testing core for example).

As the accurate 3D shape of the cooling tower is known, data for planning sensor installation or wells location can be easily computed.

Traditional geometric survey uses theodolites and well-known microtriangulation methods. It presents the advantage to provide some results close to the best possible accuracy (near 1 mm). However, the drawback is it is a "discrete" method, since it focuses on limited number of points, usually few tens (target, reflectors), not necessary placed on critical parts.

Even if SCANSITES 3D® is less accurate, the high density scan produces some surface definitions near to 3-4 mm uncertainty. Usually working with few million points, we get global information. It widely improves the sensitivity of the geometric diagnosis, showing all details.

In addition, the geometrical surveys with LIDAR were much quicker to carry out than the traditional geodesic method. The survey obtained in this way does not suffer of the shell movements and deflections due to thermal variations during the survey.

Another advantage is these methods work on every structure, even if there is no surveying equipment such as targets.

All data (photo, geometric survey, defects maps and evolutions) are overlaid on a same file. The engineer gets a faster way to make his diagnosis compared to the fastidious data fusion imposed by separated reports.

The last advantage is to store all collected data in a database, offering efficient tools to measure the structure ageing and widely a “fleet” of structures.

All these jobs are performed without rope access, increasing dramatically the safety conditions.

CONCLUSION

We’ve presented a new and modern approach for visual inspection and geometric survey, here focused on cooling towers, with SCANSITES 3D®. This method is particularly adapted to every structure which needs the resuming of its monitoring program, because it provides an exhaustive inventory. It also permits to readjust an existing monitoring program by completing the lacks forgotten by classical approaches. Not only is this method adapted to concrete structures, but it can also be used on old construction, masonry-work, clay works… The correlations between defects and deflections are finally some precious information to locate the areas where geodic surveying and sensors have to focus on. Moreover, besides useful results for the monitoring, the SCANSITES 3D® provides as-existing mappings which are often lacking on old structures. This method is widely applicable on large structures such as dams, but also skyscrapers, chimneys... The next step, in progress, is to overlay a high accuracy thermographic imagery survey. The aim is to study the possible gain in diagnosis, mainly on cracks.