STRESS-STRAIN STATE OF OIL TANKS FOR TERRESTRIAL LASER SCANNING MODEL

НАПРЯЖЕННО-ДЕФОРМИРОВАННОЕ СОСТОЯНИЕ РЕЗЕРВУАРОВ ПО РЕЗУЛЬТАТАМ НАЗЕМНОГО ЛАЗЕРНОГО СКАНИРОВАНИЯ

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Abstract: *The paper proposes a methodology for applying three-dimensional laser scanning to obtain an accurate three-dimensional models that will be used to calculate the stress-strain state of constructions of tanks for oil and gas.*

Keywords: GEODETIC INSPECTION, STRESS-STRAIN STATE, TERRESTRIAL LASER SCANNING, VERTICAL STEEL TANKS

1. Introduction

The paper proposes a methodology for applying three-dimensional laser scanning to obtain an accurate three-dimensional models that will be used to calculate the stress-strain state of constructions of tanks for oil and gas.

In the process of operation of the vertical steel tank it purchases a significant deviation from its design position and status. In particular, forms sludge in the tanks (uniform and non-uniform) and change of their geometric shapes (deviation of the generatrix from the vertical, indentations, curves, etc.).

2. Preconditions and means for resolving the problem

The decision making on the need to carry out work on the restoration of the state of the tank is made on the basis of two parallel and interrelated criteria:

1) comparison of data on the spatial position of the tank and its geometric shape, obtained in the process of geodetic inspection, with tabular data presented in normative documents;

2) determination of stress-strain state defects of the tank on the basis of geodetic inspection data.

However, this system has a number of significant disadvantages, including the following:

- Low level of detail in data on the spatial position and geometric shape of the tanks after the geodetic inspection. The data obtained during the geodetic inspection, allow only in general terms, by key points (in particular intersections forming with horizontal welds) to judge the actual geometric shape of the tank. Thus the form of a surface of the wall, lying between these points, except for inadmissible indentations (bulges), remains for us "unknown". In particular, it is possible to judge only approximately where this or that indentation (bulge) begins and ends, where the wall coincides with the vertical, etc.;

- High labor intensity of the work and subsequent post processing of the data of the tank geodetic inspection. The specialist in geodetic inspections is required to manually measure the spatial position of each necessary point, the number of which increases significantly with the increase in the volume of VST. In the presence of unacceptable indentations (bulges) the number of required measurements increases even more. Also, a significant amount of work must be done during the cameral processing of the data and the construction of a three-dimensional computer model of the tank;
- Long term performance of works;

- The need for additional travel to the object, when detecting errors in the geodetic inspection at the stage of the cameral processing of the data;

- High probability of errors (human factor) due to low automation of the process. In this case, it should be noted that the criticality of defects subject to additional measurement, in fact, is determined visually by a specialist conducting work on the geodetic inspection of the tank. At the same time, there is a high probability of errors, in which part of the critical defects will not be reflected in the results of the survey;

- Decide on the necessary repair of the tank according to standard tabular data occurs when the separate consideration of non-uniform sludge in the tanks and a forming deviation from the vertical. Moreover, if we analyze the values of the critical values specified in the regulations, we can establish that most of them were specified in the SN 26-58 “Technical conditions of manufacture and installation of steel cylindrical vertical tanks for storage of oil and petroleum products”;

- There is no specific method for calculating the stress-strain state of tanks in operation. All of the above says that the existing system for monitoring the spatial position of vertical steel tanks and determining their stress-strain state should be, if not changed, at least upgraded on the basis of the use of modern high-tech and high-performance measuring instruments and software systems. The solution to this situation can be the use of ground-based three-dimensional laser scanning and software systems that implement the finite element method. [1], [2], [3]

3. Solution of the examined problem

Laser scanning technology is based on measuring the distance from the laser rangefinder to the surface of the scanned object and two angles (horizontal and vertical) that determine the direction of the vector from the laser rangefinder to the object in the coordinate system of the laser scanner. The spatial vector determines the position of the surface point of the object being scanned. As a result, a cloud of surface points of the scanned object is formed, which reflects the real information about its spatial position and its geometric shape.

In other words, the technology of laser scanning represents a new stage in the development of technology of electronic total stations, in which a subject is being shot in automatic mode.

The technology of three-dimensional laser scanning was analyzed by the employees of the Department of Construction and repair of oil pipelines and storages of Gubkin Russian state University of oil and gas (NIU), were considered the main features of its applications, features of different generations of laser scanners and their characteristics. As a result, a new approach to this technology was proposed. Precisely the consideration of laser scanners not as a replacement of existing surveying instruments, but as a conceptually and technologically new diagnostic device that opens up new opportunities.

So laser scanning was subjected to tanks with a pontoon volume of 5000 and 20000 m^3, located in earthen banking. Tanks of this volume are most common in the oil industry of Russia, and the earthen can improve the convenience of the scanner location when shooting. The tanks were emptied and prepared for repair.

4. Results and discussion

As a result of the performed works, clouds of points of both tanks were obtained, which were further processed in specialized software complexes to obtain three-dimensional models of the surface of the walls, suitable for the analysis of their stress-strain state in programs implementing the finite element method.

To perform the comparative analysis, models of stress-strain state of the real wall of vertical steel cylindrical tank-5000 (figure 1 and 2) and vertical steel cylindrical tank-20000 (figure 3 and 4), as well as the ideal wall of these tanks (figure 5, 6, 7), were constructed. The models were loaded with hydrostatic load.

A comparison of this models shows:

The stress-strain state of the model of the" real " tank wall obtained by three-dimensional laser scanning reflects the real state of the wall much more accurately and in more details than any idealized models;

- The pattern of deformations of the real wall model differs significantly from the deformations of the ideal model, both in terms of values and the nature of the distribution of deformation on the wall. For example, for VST-5000, the maximum deformation of the real wall is 1.5 times greater than the deformation in the ideal model, and the location of the maximum deformation zones is determined primarily by the defects in the geometry of the wall, rather than by the applied load. For VST-20000, the deformations of the real wall differ significantly from those of the ideal wall due to the presence of a significant number of geometric defects on the wall.

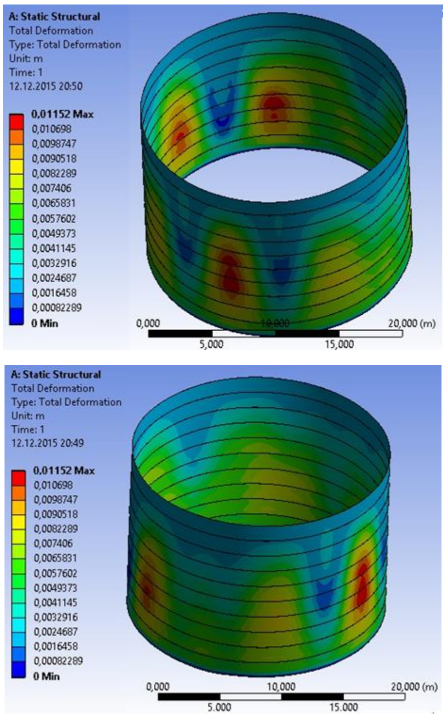

Fig. 1 *Deformation of a three-dimensional model of a "real" wall of vertical steel cylindrical tank-5000, m*

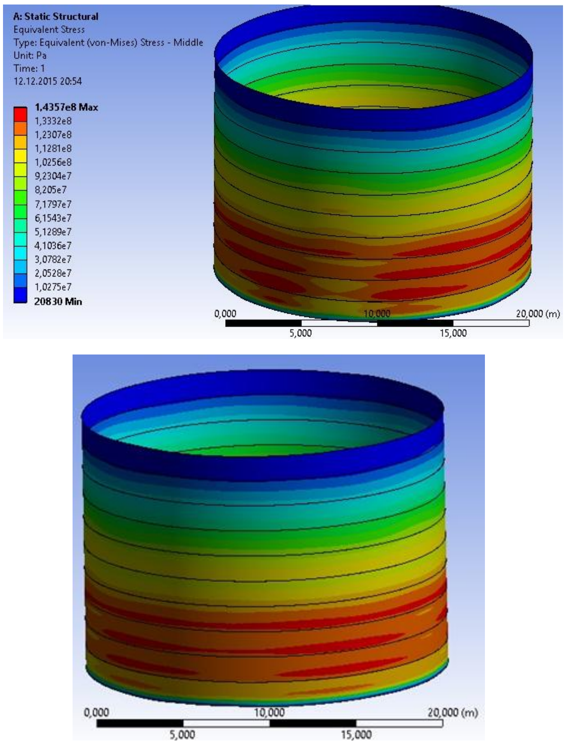

Fig. 2 *Median equivalent stresses according to Mises three-dimensional model of the "real" wall of vertical steel cylindrical tank -5000, Pa*

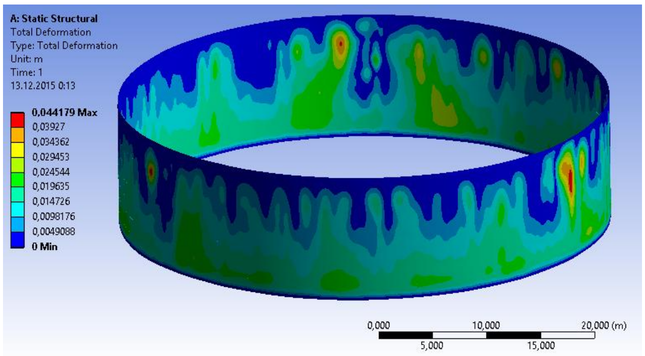

Fig. 3 *Deformation three-dimensional model of the "real"*

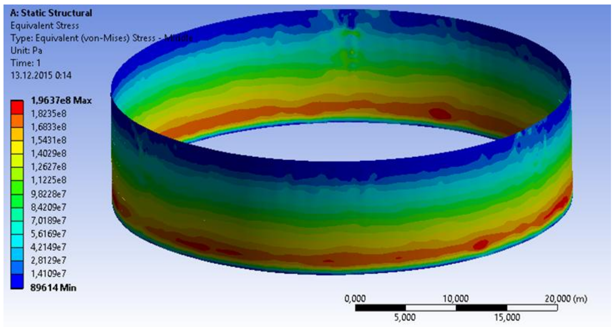

Fig. 4 *Median equivalent stresses according to Mises three-dimensional model of the "real" wall of vertical steel cylindrical tank -20000, Pa*

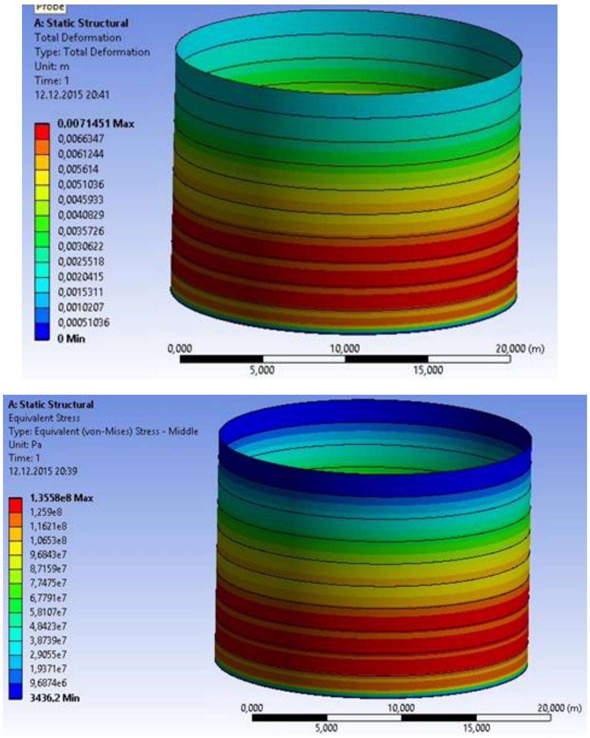

Fig. 5 *Deformation and median equivalent stress according to Mises three-dimensional model of «ideal» wall of vertical steel cylindrical tank-5000, m*

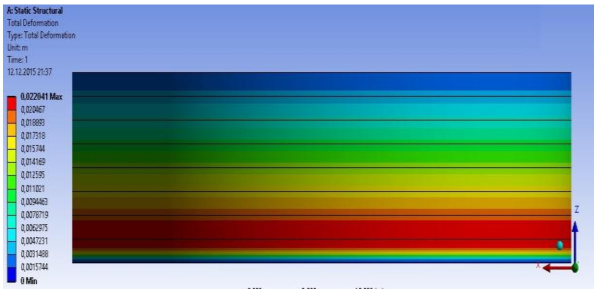

Fig. 6 *Deformation of a three-dimensional model of an "ideal" wall of vertical steel cylindrical tank-20000, m*

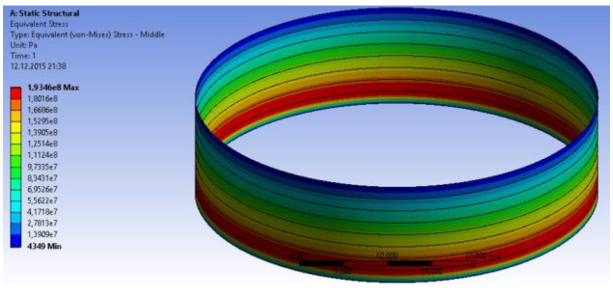

Fig. 7 *Median "equivalent" stresses according to Mises three-dimensional model of an "ideal" wall of vertical steel cylindrical tank -20000, Pa*

• It should be noted that the actual tank wall may be characterized by geometry defects such as indentations. Which will remain even under hydrostatic load (figure 8).

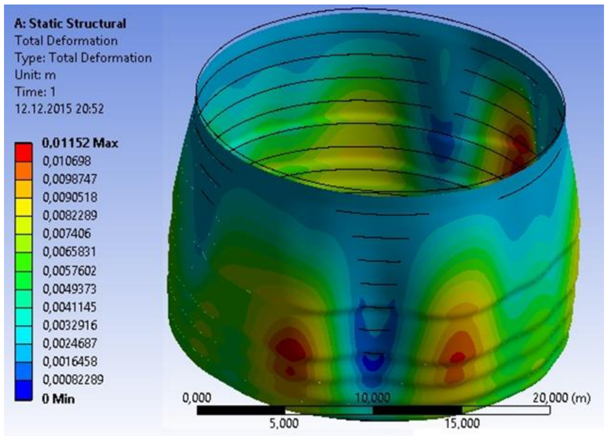

Fig. 8 *Deformation of the real wall vertical steel cylindrical tanks-5000 in scale (black curves show the location of the rings without load), m*

• The stress in the real wall of the tank is also different from the stresses generated in the wall of the ideal model. For example, the value of the equivalent mid-point stresses according to Mises model for each of the rings of the real wall of the VST-5000 is on average 10% more than the same stresses in the case of the ideal wall.

Conclusions: During operation the number of geometry defects increases and they begin to have a significant impact on the stress-strain state of these tanks. In order to determine their technical conditions and residual life, these defects should be taken into account to prevent the occurrence of an emergency situation. Widespread and used well-known geodetic methods for monitoring the geometry of tanks allow to assess the defects in geometry only at certain points that are significantly (up to 6 m) distant from each other. When modeling using this data, the surface of the tank between these points is restored by approximation methods using an ideal model that does not reflect the real geometry and its defects and does not allow to obtain reliable models of the stress-strain state.

The use of three-dimensional laser scanning when creating a strain-stressed state allows to avoid these disadvantages and to obtain the most realistic values of the parameters of the strain-stressed state for a tank in operation.

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