An evaluation of additional criteria for assessing the condition of oil terminal tanks with the aim of extending safe service life - Part 1

by A.A. Katanov*[1], M.V. Likhovtsev[1], and D.A. Bushnev[2]

[1] Pipeline Transport Institute, Moscow, Russian Federation
[2] JSC Transneft Diascan, Lukhovitsy, Moscow Region, Russian Federation

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A B S T R A C T

This article examines topical issues regarding the monitoring technical condition for vertical cylindrical tanks of oil terminals. It presents an analysis of standards in the Russian Federation and abroad for tank technical diagnostics in the area of strength calculations when determining the remaining lifetime of tank structures. The possibility of using laser scanning technology to evaluate tank technical condition is also demonstrated.

Standards in the Russian Federation, unlike abroad, recommend carrying out strength calculations of tank structures using finite element methods and 3D models. These 3D models correspond to the real geometric shapes of structures, which are mapped using discrete geodesic surveying. Surface laser scanning technologies (SLS) have been in use in both domestic and foreign practice for over 12 years. They enable the geometric parameters of structures to be checked with high accuracy during operation.

The issue. SLS technologies have not previously been used in the Russian Federation to develop computer models of tank structures for strength calculations and measurements using finite element methods.

Key words: storage tanks, oil terminal, safe lifetime extension

1. Introduction

In accordance with guidelines from the United Nations Economic Commission for Europe ECE/CP.TEIA/28 (Guidelines on safety and good industry practices for oil terminals) oil terminals are defined as facilities for oil and oil products storage, including loading, unloading and transfer operations, which operate either separately or within larger industrial facilities, such as trunk oil-product pipelines and oil refineries. Huge quantities of hazardous substances are stored at oil terminals, posing a risk to humans and to the environment, especially in the case of substandard design, construction, management, operation or maintenance. An accident at an oil terminal can lead to uncontrolled spills, fires and explosions, potentially leading to fatalities or a large-scale environmental disaster.

*Corresponding author: Aleksey A. Katanov, e-mail: KatanovAA@niitnn.transneft.ru
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One of the main components of oil terminals are tank farms, consisting of vertical cylindrical tanks with large volumes (more than 50,000 m^3). Their reliability can be reduced during operation as a result of a gradual change in structural geometry, corrosive wear and ageing of steel. These changes occur due to the impact of many physical, mechanical and chemical factors. Such factors include: the heterogeneity of materials; progressing subsidence in the foundations; increasing stress intensity, which leads to microfractures in the material; sudden temperature changes; exposure to atmospheric precipitation; and impacts caused by the consequences of accidents arising during operation.

In this situation, qualitative evaluation of the risks of further operation and tank technical condition is extremely relevant. Tasks such as this are resolved in the course of technical diagnostics, which is carried out at specified periods of time in accordance with the following documents:

- API STD 653-2009 *Tank Inspection, Repair, Alteration, and Reconstruction*, API RP 579 Fitness-for-Service - for the USA and Europe;
- SG *Guidelines for the technical diagnostics of welded vertical cylindrical tanks for oil and oil products* - for the Russian Federation; RD-23.020.00-KTN-141-16
- Trunk pipeline transportation of oil and oil products. *Rules for technical diagnostics of tanks* - for PJSC Transneft.

In accordance with the documents listed above, tank structures are evaluated by a range of criteria when determining the remaining lifetime in order to schedule the next technical diagnostics (inspection). One of these criteria is the result of strength calculations for tank structure elements.

Unlike foreign standards, the regulatory documents of the Russian Federation specify that these calculations should include:

- calculation of the stress-strain state (taking into account the actual thicknesses) of the tank wall and elements of the tank bottom, and based on the actual geometric shape of the structures, local deformations (dents, bulges), and the ‘angularity’ of welded joints, stiffening ribs and rings. Unlike foreign standards, these guidelines recommend that calculations are carried out using 3D computer modelling with software packages which apply finite element methods.
- calculation of welded joints for low-cycle fatigue.

Based on the results of the calculation, the degree of danger due to any defects detected is determined in order to continue operating the tank. The values of the maximum and minimum stresses are also determined to check for low-cycle fatigue.

Inspection of the stress-strain state of structures that deviate from design geometry (dents, bulges, clearance gaps, vertical deviations) is possible only on the basis of finite element calculations, taking into account the actual geometric shape. This is an additional criterion which increases the reliability of the calculations and ultimately has a significant impact on determining the further safe operating life of the tank structure. To achieve this, discrete geodetic surveying methods (point coordinates at fixed intervals) using optical theodolites and laser tachymeters were applied.

To improve the efficiency of monitoring the technical condition of structures and buildings in domestic and international practice, surface laser scanning technologies (hereafter SLS) have been in use for more than 12 years. The technology of laser scanning is based on the use of a laser reflectorless distance meter, which is built into the device with an automatic change of the laser beam direction. After setting the scanning area, a total survey of the object of interest in the device’s viewing area can be taken. The coverage density (the surface discretization) of the object scanned with a laser beam is to 0.25 mm. The scans are then used to create a pixel array that describes the object of the survey.

The SLS process is a sequence of operations to collect and store information about the spatial location of survey objects. The information is presented as a three-dimensional point cloud, which can be used to develop the computer models of structures and to perform the necessary measurements and calculations.

2. The issue

Modern models of laser scanners enable objects to be scanned with a resolution (the interval between two points at a scan distance of 10 m) from 0.6 to 50 mm / 10 m. This significantly affects the time of laser scanning (from 2 to 5 hours) and of processing results to prepare computer models of structures (from 1 to 6 hours_ SLS technologies to perform necessary calculations and measurements by finite element methods have not previously been used in the Russian Federation for developing computer models of tank structures. There were no recommendations for selecting the optimal resolution to carry out SLS, or a sequence of operations to process the SLS data in order to obtain 3D models for carrying out calculations by finite element method.

Existing software did not enable performing computer-aided operations to monitor the local deviations from the tank design shape.

3. Research

In 2014-2017, within the framework of research programmes conducted by PJSC Transneft, OJSC PTI Transneft together with Gubkin National Research University and JSC Transneft-Diascan, work was carried out to study the possibility of using SLS for monitoring the geometric parameters of tanks during construction, repair and technical diagnostics.

The work was conducted in two stages. At the first stage, the following operations were carried out:

- an evaluation of the accuracy of measurements made using SLS;
- an evaluation of software capabilities for processing SLS data;
- development of a methodology for monitoring the geometric parameters of tanks by the SLS method.

At the second stage the following steps were made:

- recommendations were developed for the use of tank SLS data in computer modelling when carrying out strength calculations and stress-strain state evaluation, depending on the scan resolution and on parameters for converting the elements of the computer models of programmes that implement the finite element methods;

In Part 2 of this paper, to be published in December (Vol.2, No.4), the authors present a detailed discussion of their technology and is application in this context, and give their conclusions.

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