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Srength Characteristics of Liquid Storage Tanks with Nanocomposites as Reservoir Materials

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***Abstract*—The objective of this research is developing effective methods to estimate static and dynamic strength characteristic of liquid storage tanks. Fluid-filled reservoirs made of different nanocomposite materials are considered using concept of representative volume element. Static and dynamic analyses are accomplished. Free and forced vibrations of the elastic shells of revolution, partially filled with an ideal incompressible fluid are analysed. Finite and boundary element methods are used for numerical implementation. It has been demonstrated that the lowest own frequencies of elastic reservoirs are corresponded to sloshing. To reduce the sloshing amplitude, it is proposed to use a floating cover in the form of an elastic membrane. The results of the calculations have been shown that the use of composite materials with nanoinclusions in the form of steel spheres is the best option for environmentally friendly operation of tanks under intensive loads.**

Keywords—liquid storage tank, nanocomposites, representative volume element, environmental safety, elastic cover

I. INTRODUCTION

Storage tanks for hydrocarbons and other chemically and biologically hazardous liquids are the objects of heightened environmental danger. It is necessary to perform additional calculations and develop appropriate design solutions to minimize the risks of their accidents in the event of earthquakes or explosions. The degree of damage to the environmentally hazardous object during the earthquake depends not only on the seismic effects level, but also on the quality of seismic design and construction.

The possibility of exposure to smaller but more frequent and prolonged seismic or impulse loads caused by technogenic and natural factors has not been sufficiently taken into account in tanks designing as dangerous liquid storages. Containers and tanks for environmentally hazardous liquids storage are widely used in various engineering practice areas. These tanks are operating under high technological loads and filling with oil, flammable or toxic substances. As a result of the sudden action of seismic or impact loads, the liquid stored in the tanks, begins to experience the intense splashes.

Sloshing is a phenomenon in the number of industrial facilities: in containers for storage of liquefied gas, oil, fuel tanks, in the reservoirs of cargo tanks. It is known that partially filled tanks are exposed to particularly intense splashes. This could lead to high pressure on the tank walls, destruction of the structure or loss of stability and can cause the release of environmentally hazardous contents into the environment and lead to serious consequences [1-4].

To design the liquid hydrocarbon storage tanks that are objects of environmental danger, according to current building standards, it is necessary to take into account the 1% probability of exceeding the estimated intensity of seismic impacts for 50 years. This factor also significantly increases the risks of trouble-free operation and, accordingly, the cost and complexity of construction of these engineering structures.

According to recent seismological studies, it has been established that in Ukraine, including its platform part, there is the danger of local and strong subcortical earthquakes with magnitudes more than 5 points [5-7].

According to the existing standards [6], the foundation ring is calculated for the main load combinations, and for construction sites with seismicity of 7 points and above is for the special load combinations.

Liquid spills could lead to explosions and fires that could spread to nearby reservoirs and surrounding areas. Economic losses from accidents with tanks destruction, leakage and fire of liquid hydrocarbons include not only direct losses, but also the cost of measures to restore the environment [8]. The release of dangerous liquids from storage tanks and its further spread to the territory of settlements could cause mass poisoning of people and animals, lead to environment pollution.

To ensure the environmental safety of areas adjacent to tanks filled with liquid hydrocarbons, it is necessary to take into account the safe design of the tank, tank material, forecasting the effects of natural and technogenic factors on tanks. The set of natural factors that must be taken into account are seismic loads, groundwater level of the reservoir location and others. Technogenic factors should include sudden traffic accidents, industrial accidents, vibration, seismic and artificial impacts, and so on.

In research papers of Shevtsov A. A. [8], Wilson S. [9] Islamovic F. [10], Godoy L.A. [11], Jaca R.C. [12] the significance estimation of tanks influences for liquid hydrocarbons storage on environment and monitoring of reservoirs tightness changes, the destruction rate of their structure under the technogenic and natural factors action have been investigated. The issues concerned with liquid sloshing in tanks have been conducted in the works of Ibrahim R.A. [13]. Seismic and impact loads on thin shells were considered in [14-16].

The necessity of control and impact assessment of nanomaterials on the environment for safety and efficient use of nanotechnologies has been substantiated in [2]. In the

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frequencies and modes of vibrations of fluid-filled elastic tanks with nanocomposites as reservoir materials.

Modal analysis of various type of nanocomposites showed that using different types of inclusions when creating thin-walled shells allow us to change the strength characteristics and detuning from the resonant frequencies of the shell without changing the geometric parameters. It will be critical in certain situations, for example, when upgrading existing structures, eliminating the need to replace a large number of parts.

The composite materials using with nanoinclusions in tanks for storage dangerous and flammable liquids, allow to increase the reliability of tanks under seismic and impact loads and to extend their service life under the influence of natural and technogenic influences of various origin. The results of the calculations have been shown that the use of composite materials with nanoinclusions in the steel spheres form is the best option for environmentally friendly operation of tanks under seismic loads. In accordance with the calculations, the use of, primarily porous, nanoinclusions will reduce the weight of elements of aviation and rocket technology maintaining the sufficient level of strength, thereby increasing its flight characteristics.

The results obtained in the hydrostatic analysis allow to conclude that using lamellar and fibrous radially oriented nanoinclusions can significantly increase the strength of structures in the radial direction without the use of stiffening belts.

In general, the calculations indicate only the situational usefulness of randomly filled nanocomposites and lead to necessity of developing methods for creating structured nanocomposites in order to obtain highly orthotropic properties of a new material.

Provided calculations have been allowed to build the necessary systems of basic functions not only for the forced vibrations study, but also for simulation of the surface tension influence and nonlinear effects on vibrations of fluid-filled tanks.

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