Parameter selection of hydraulic jack for repair of oil tanks in the Far North conditions

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Abstract. The petroleum industry is a key component of the Russian Federation economy. A large number of reservoirs are used for oil storage, each of which needs timely repair. According to the research results almost half of the accidents are caused by excessive irregularity of reservoir settlement, which causes their premature failure. In order to restore the faultless and serviceable condition of the tanks, it is necessary to carry out repair works, the quality and efficiency of which depends on the used repair equipment. The actual problem is the substantiation of the choice of equipment for repair of tanks, in particular steel tanks of vertical type. The review of different types of tanks was carried out and it showed that vertical steel tanks are the most widespread. One of the ways to eliminate uneven tank settlement is to lift the tank with the help of jacks and form a new base with the removal of the slope. The process of repairing a vertical steel reservoir with a volume of 10000 m^3 was considered. The values of the tank mass when filled with liquid petroleum products at 1% of the maximum filling capacity have been obtained. The load value on one lifting device was obtained. The design of the structure of the device and the strength calculation in the program Compass 3D were performed. The most effective type of hoist was determined from the existing ones, and its design was upgraded. The strength calculation showed that the hydraulic elevator is operable under the given conditions. **Key words:** tank repair, lifting device, steel tank, tank lifting method, storage of petroleum products.

1 Introduction

To maintain tanks in a technically sound condition, scheduled preventive maintenance is carried out, including inspection, current and overhaul of the tank itself and all tank equipment. The repair of the tank tanks is an integral part of the planned repair and reconstruction of the objects. The scope of work is included in the section "Tank batteries" of comprehensive programs of diagnosis, technical re-equipment, reconstruction and major repairs of objects of main oil pipelines [1, 2, 3, 4, 5, 6]. The choice of the tank capacity for its repair is based on the assessment of its technical condition.

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The data for the analysis and assessment of the technical condition of the tank capacity are [7, 8]:

- diagnostic results;
- information about the previously detected and corrected defects;
- data from the technical passport of the tank.

The actual location of the production facilities, the tendency of petroleum productions development in the Far North and the necessity to increase the storage capacity require the construction, and consequently the further operation and maintenance of large-size tanks in the areas represented by muddy, permafrost and heterogeneous soils unfavorable for tank construction; quite often there is a question about the repair of bases and foundations [9, 10, 11, 12, 13, 14, 15].

There are several possible causes of oil reservoirs failure. The main causes are presented in the form of a diagram in Fig. 1.

Based on the obtained results it is evident that the main reasons for the destruction of the tanks are excessive settlements of the base, so increasing the reliability of the bases of tanks in order to reduce emergency situations is an urgent task.

There are several types of tanks for liquid petroleum products storage. Underground storages are arranged in natural or artificial cavities under the ground.

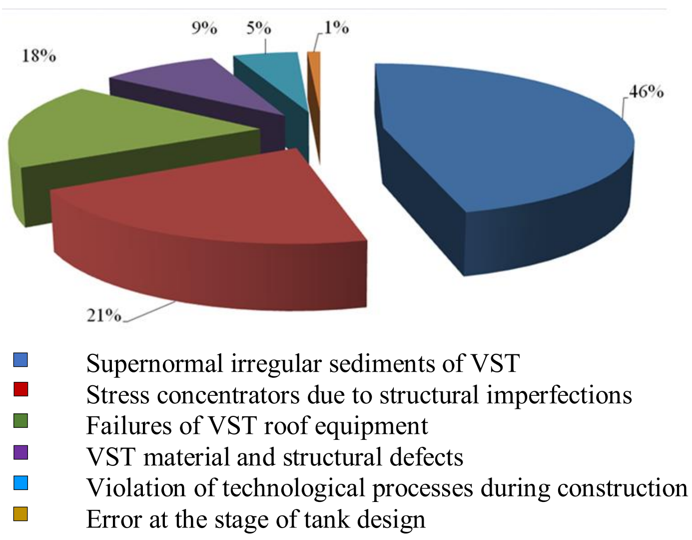

Fig. 1. The main causes of tank failure.

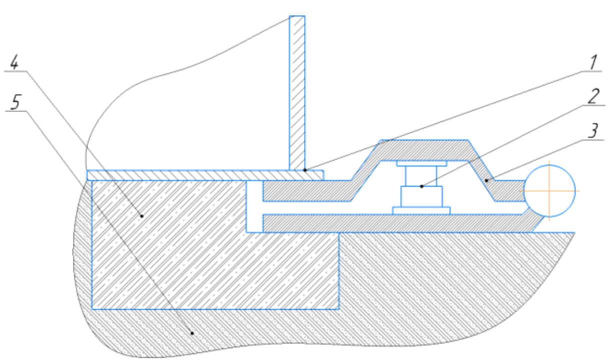

Fig. 2. Hydraulic scissor elevator: 1 - tank; 2 - hydraulic jack; 3 - lifting device; 4 - tank foundation; 5 - soil base.

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There are also horizontal storage tanks of small volume (up to 100 m^3). Among the large-capacity above-ground tanks there are reinforced concrete and vertical steel tanks. Their capacity can be 10-100 thousand m^3. Based on the advantages and disadvantages of different types of tanks and analyzing the actual application, the majority of tanks in oil and gas enterprises, including those in the northern regions, are vertical steel tanks (Fig. 2).

Fig. 3. Vertical steel tank.

Most often tanks are erected on sites represented by clay and loamy soils, or rock formations. The choice of foundation type is important in ensuring the stability and durability of the entire structure. Proper preparation of the base and the foundation will reduce the impact of precipitation and groundwater, and thus facilitate future operation and prolong the period between repairs.

In the practice of tank construction in our country, the most economical and thus most common is the construction on a natural base. This is done by leveling works on the site and arranging sand or soil cushion. This type of foundation has one major drawback. After a while the foundation of the tank has an uneven bottom shrinkage or roll. This defect affects the concentration of stresses in places of welded joints, and also creates unnormative moment at the junction of the bottom and the tank wall, which is largely due to the weak carrying capacity of the soil.

Based on the above, it can be seen that it is necessary to investigate the repair of defects related to tank settlement.

Since uneven sedimentation of tank bases is often the cause of VST accidents, the process of repairing this defect will be discussed below. One of the devices used in repair work is a hydraulic jack to lift the tank. There is a way to raise the tank by digging under the ground and installing the jack in the created niche. The disadvantages of this method include a large amount of excavation work, which is difficult to carry out in the Far North, as well as the inability to restore the foundation to its original strength. The tank can be lifted in another way. Inventory stiffeners are welded to the side surface of the tank. To do the lifting, a column is attached to the stiffeners together with a hydraulic jack. The disadvantage of this method is the necessity to weld stiffeners and then remove them after the job is done.

Earlier the domestic oil and gas specialists developed a method of oil tanks lifting with the help of hydraulic scissor jack (Fig.3). The main advantages of this method in comparison with others are: low interference, integrity of the tank foundation, and small volume of excavation works; possibility to perform repair works without emptying and cleaning the tank.

To eliminate slope or sag of the tank use a number of devices of this type, placing them around the repaired tank. Let's consider the process of tank repair of a nominal volume of

10000 m^3 with the use of a hydraulic hoist of this type. During overhaul repair of steel tanks, the reservoir should be completely taken out of service. It is necessarily emptied, degassed and cleaned from corrosion. As part of the work, the technical condition of all elements is assessed.

2 Methods and Materials

To determine the number of hydraulic elevators and the load falling on them, it is necessary to perform a calculation according to the methodology below.

The input data for the calculation are presented in Table 1.

From the technical data we know that the reservoir mass is m_r= 234346 kg, and its diameter D = 34.20 m. Assume that the VST is filled to 1% of the nominal volume. Based on the calculated filling height, equal to 11.20 m, the height of the column at ten percent fullness will be 0.11 m. Then the volume of oil will be V = 101 m^3. Let's find the mass of oil m_y at 1% of the tank filling according to the formula

$$m_o = V_r \cdot \rho, \tag{1}$$

here ρ – oil density, it is assumed 0.889 t/m^3.

$$m_o = 101 \cdot 0.889 = 89.8t$$

Thus, the total mass of the tank filled with oil to a given value will be M = 324146 kg.

The force of gravity acting on the base of the tank is calculated by the formula (2):

$$F_{gr} = g \cdot M, \tag{2}$$

here g is gravity acceleration, m/s^2.

$$F_{gr} = 9.81 \cdot 324146 = 3179872.3 \text{ N}.$$

It is advisable to convert this value to kN. We obtain F_{gr}= 3179.9 kN.

Table 1. VST-10000 Technical Characteristics.

Name	Value
Volume, m3	10000
Filling height, m	11.2
Diameter, m	34.2
Wall thickness, mm	10
Weight, kg	234346

Table 2. Strength calculation parameters.

Name	Value
Steel grade	3 kp
Yield strength, MPa	235
Density, kg/m^3	7800
Compressive strength, MPa	410

In accordance with the typical technology of lifting the tank props for lifting the tank are welded to a step of 4 m, respectively, the jacks are installed at the same step, the modernization of the technology will take the same step of installation devices type "scissors".

For the selected tank number of jacks, based on the perimeter of the tank, which is equal to 107.44 m, take the number of jacks equal to 27 pcs. The force acting on one device will be 117.77 kN, which is ~ 12000 kg.

We will take 15000 kg as optimal variant for lifting capacity and cost. This variant of hydraulic jack provides keeping the load at the given height and increasing reliability in operation.

The design of the lifting device was designed with the help of CAD system Compass 3D (Fig. 4).

After designing the design, a strength analysis was performed using the built-in APMFEM utility. The strength calculation parameters are presented in Table 2. The following finite element mesh parameters were set during construction: 4-node tetrahedrons with an element side length equal to 10 mm. The densification coefficient is equal to one. Such parameters are optimal for calculations of simple structures because using 10-node tetrahedrons and smaller length of finite elements practically does not increase the accuracy, at that more computing resources are spent. The anchoring points are chosen to meet the condition that the displacement of the mechanism during its operation is zero. The load application for the upper part of the device corresponds to the reaction from the tank being lifted, and for the lower part of the device, to the support reaction from the load transfer through the hydraulic jack (Fig. 5).

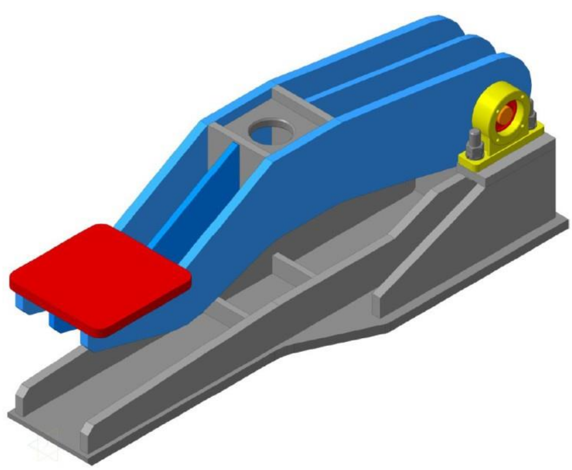
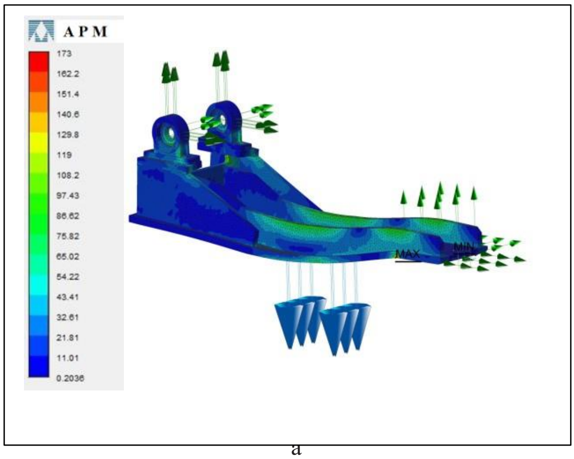


Fig. 4. Scissor-type hydraulic elevator.

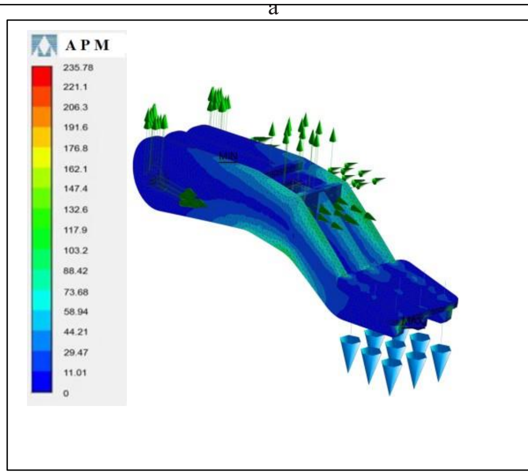
3 Results

The strength calculation was performed for the model of the lower and upper part of the lifting device separately. The results of the static calculation of the strength by the finite element method are shown in Fig. 5.

The analysis of the obtained results shows the following. The greatest stress in the upper part of the lifting device occurs in the bending area near the hydraulic jack rod, as well as in its extreme part at the point of load application. For the lower part of the lifting device, the greatest stresses occur near the base of the jack. The maximum stress value of the lower part of the jack reaches 173 MPa. For the upper part of the jack it is 236 MPa.



a



b

Fig. 5. Equivalent voltage according to Mises:a - bottom of the device; b - top of the device.

4 Conclusion

Steel tanks are widely used for storage of liquid petroleum products. As they are in use, it is necessary to carry out repair work to keep them in good condition and prevent accidents. A hydraulic jack is one of the devices necessary for carrying out the work. The conducted research allowed us to reveal the most effective type of such jack and improve its design. In order to calculate the strength, a load higher than the design load of 16 kN was set. At the same time the maximum yield stress was 236 MPa, which indicates the possibility of using this type of device in the repair of a steel tank with a volume of 10000 m^3.

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