Analytical Aspects of Special Purpose Metal Structures Design

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ABSTRACT

In the article, features and properties of building constructions of a special purpose are considered. There are presented analytical aspects of design and calculation of oilfield metal structures – tanks, shells, pipelines and fixed offshore platforms. Types of the applied structures, the description of their design schemes including loads acting on the structure are given. Two groups of limiting states calculate designs of fixed offshore platforms.

Keywords: metal structures, sheet structures, tanks, shells, pipelines, fixed offshore platform

Received: 20-01-2018
Approved: 10-03-2018

1. INTRODUCTION

Relevance of the considered subject consists in the complex analysis of metal structures application features, the account of their physical and mechanical properties at application on objects of the special purpose.

Sheet structures applied in objects of the special purpose are continuous thin-walled spatial structures in the form of various shells, tanks and pipes, usually combining load-bearing and enclosing functions. They are used for storage, transshipment, transportation, processing of liquids, gases and bulk materials.

Joints of sheet structures elements have to meet the requirements of not only strength but also density. At the same time, the length of welded joints in sheet structures is about twice as large as in rod structures. The main type of joints in sheet structures is a butt weld, which causes the least amount of metal weld and high reliability of connection. Oversized sheet structures are characterized by extensive use of automatic and semi-automatic welding both at manufacture and installation. Physical methods are used to control the quality of welds[1].

In General, all metal structures can be divided into the following groups: sheet structures for shells, sheet structures for storage tanks, sheet pipeline structures, structures of fixed offshore platforms.

2. SHEET STRUCTURES FOR SHELLS

The shell is called a continuous structure (or element), two limiting curved surfaces of which are spaced from each other at a very short distance, many times smaller than other sizes. An imaginary surface equidistant from both limiting surfaces is called a median surface. The geometric name of the shell is determined by the shape of its median surface (cylindrical, spherical, ellipsoidal, torispherical, etc.). In a particular case, with a flat median surface, the shell turns into a plate[2].

With regard to sheet structures, most shells are thin-walled, which are characterized by a momentless biaxial stress state, with the exception of places of abrupt changes in the load or shape of the shell, where there are local, quickly damping stress of the edge effect when removed from these places (edges). In the particular case only normal meridional and annular forces act on the shells of rotation, which are under the action of an axisymmetric load in a momentless stress state[2].

Received: 20-01-2018
Approved: 10-03-2018

The stability of shells to a much greater extent than that of rod structures depends on their shape, fastening conditions, initial imperfections, the nature of loads; therefore, in practical calculations, the stability of cylindrical, conical, spherical and other shells is considered separately [5].

3. SHEET STRUCTURES FOR STORAGE TANKS

Depending on the position in space and the geometric shape tanks are divided into vertical cylindrical, horizontal cylindrical, spherical, drop-shaped, torus, trench.

In tanks for storage of corrosive liquids it is advisable to use aluminum alloys or bi-metals - steel sheets, plated from the side of aggressive environment by stainless steel or nickel. If it is not possible, the inner surface of the tank made of ordinary steel is protected from corrosion by a perchlorvinyl or other coating [5].

Features of the tanks structures will be considered on the example of vertical cylindrical tanks.

Such tanks are mainly used at overpressure in the steam-air zone up to 2 kPa and vacuum up to 25 kPa. Vertical cylindrical tanks have a flat bottom made of steel sheets 4-6 mm thick, and walls in the form of a number of belts, the thickness of which increases in proportion to the increase in fluid pressure as it approaches the bottom. In practice there are most often applied conic, spherical or floating roofs.

Tanks are located on a fairly simple sand base due to the negligibility of the pressure transmitted to them. Around the tank provision is made for safeguard in the form of ground shafts, reinforced concrete or metal walls in order to retain the stored product when leaking from the tank in emergency cases.

The bottom of the tank consists of an even number of panels (for possibility of creating a slope), each of which does not exceed 12 m in width. The panels of the bottom are overlapped. The minimum overlap shall not be less than 30 mm.

Calculation of tank walls is run over two groups of limiting states. When designing the tank the following types of calculations should be performed[3]:

- strength calculation of the tank wall;
- stability calculation of the tank wall;
- calculation of the junction of the wall with the bottom;
- checking the stress with account of the edge effect.

Received: 20-01-2018
Approved: 10-03-2018

Roofs of vertical cylindrical tanks of low pressure with a capacity of up to 5000 m in most cases are made in the form of a conical panel roof. Much less frequently, with low snow load, a hanging, pyramidal roof is used. In larger tanks the main type is a spherical roof [3].

According to SNiP 2.11.03-93(Construction norms and specifications), the maximum capacity of tanks with a fixed roof shall not exceed 20,000 m when storing flammable liquids (e.g. gasoline), and 50,000 m when storing flammable liquids (e.g. fuel oil) [3].

For the tank service an internal rolling ladder is provided, the lower end of which is moved by a special support beam (farm) mounted on the roof. The upper end of the ladder is hinged to the tank wall. Outside the tank a stair tower is installed for maintenance of a floating roof. To give the open top wall of the tank required stiffness within its upper belt a stiffener ring is installed, which is also a walkway.

While designing it is necessary to provide a set of anti-corrosion activities. When choosing protective coatings one should take into account the degree of aggressive environmental impact on the elements of metal structures inside the tank and on its outer surfaces in the open air.

For safe operation of tanks and shells lightning protection devices are provided in the design. In this case there can be used both passive methods in the form of rod, cable, armored lightning-rod systems and active methods involving lightning-rods based on ion and laser radiation.

Vertical cylindrical tanks are the most common. However other types of tanks are also used in various fields of industry. Design features of other types of tanks should also be taken into account in their design.

4. SHEET PIPELINE STRUCTURES

Steel pipelines are structures intended for transportation of various gases, liquids, pulverized and liquefied masses. Long pipelines of large diameter are called main pipelines.

By the place of laying and type of support pipelines can be[3]:

- overhead, lying on separate supports;
- underwater, laid on the bottom of reservoirs and rivers or in trenches dug on the bottom.

Main oil pipelines and oil-products pipelines are divided into 4 classes depending on the diameter [3]:

Received: 20-01-2018
Approved: 10-03-2018

Class 1 - with a diameter of more than 1000 mm;

Class 2 - 500 < D < 1000 mm;

Class 3 - 300 < D < 500 mm;

4 class - < 300 mm.

Depending on the internal pressure pipelines are divided into pressure and free-flow ones. Pressure pipelines can be of high, medium and low pressure (in the range from 0.7 to 10 MPa).

When pipe sizing the following external influences should be taken into account [4]:

-internal fluid pressure with regard to hydraulic impact or gas pressure;

- longitudinal forces caused by the internal pressure of the liquid or gas when the diameter of the pipeline changes and at on its turns;
- forces acting on the bearing faces of goose necks, flaps, plugs, etc.;
- transverse loads in the form of the pipeline's own weight and the weight of the enclosed liquid (or dust);
- friction forces of the pipe on intermediate supports and in goose necks;
- friction forces of the fluid against the pipeline wall;
- centrifugal forces at the curved or sloping sections of the route;
- effects resulting from unequal settling of supports;

-the backfilling pressure, the elastic resistance of the soil, the groundwater pressure (for underground pipelines).

Additional loads are the following: an unexpected increase in the internal pressure when there is a violation in the normal work of controlling devices; vacuum arising from emptying the pipeline; effects arising from partial filling of the pipeline during its filling or emptying; wind load; ice load; load from the action of solar radiation; effects arising from the installation and dismantling of the pipeline; effects arising from hydraulic testing of the pipeline[4].

Special loads and impacts include seismic impacts, water pressure in the catastrophic floods, severe ground setting, landslides, etc.

The design scheme of the underground pipeline should reflect the interaction of the structure with the surrounding soil, which is not only a load, but also an elastic medium in which deformations of the pipeline occur, and this significantly reduces bending moments and increases the bearing capacity of the pipeline structure.

Received: 20-01-2018
Approved: 10-03-2018

The scheme of the underground pipelines laying is usually taken the same as above-ground pipelines with compensation areas.

The underground pipelines lying on the continuous basis and backfilled are distinguished by design schemes depending on existence or absence of cross-sectional reinforcing rings and length of the pipeline. The design scheme of a large-diameter underground pipeline (more than 1.2 m) in the presence of reinforcing rings is a cylindrical shell of finite length. The design scheme of an underground pipeline of any diameter in the absence of reinforcing rings is an infinitely long cylindrical shell, from which a ring of single width is cut. In both cases, calculations are made for transverse loads and impacts[1].

At simultaneous action on an underground pipe of external loadings and internal pressure the round cross section of a pipe can take the elliptical form.

The influence of soil pressure for the underground pipeline increases with the increase of soil density and the increase of the radius ratio (r/l).

For free-flow and low pressure pipelines longitudinal forces N are small, while in pressure pipelines longitudinal forces N are significant, which can lead to their unfavorable combination with efforts M and cause brittle destruction of the material.

The greatest danger for the operation of pipelines is the development of corrosion processes on the inner surface of pipes. They are the main cause of failure of pipelines [7].

To date, the main method of the service life increasing of the oilfield equipment, storage tanks and oil treatment equipment, pipelines is the use of high-performance insulating protective coatings. These coatings should optimally have high weather and moisture resistance, resistance to aggressive media, should be non-porous, have high adhesion to metal, high mechanical bending and impact strength, long service life.

5. STRUCTURES OF FIXED OFFSHORE PLATFORMS

The offshore stationary platform is a unique hydraulic structure designed for installation of drilling, production and auxiliary equipment for the drilling of wells, extraction of oil and gas, as well as other works associated with the development of offshore oil and gas fields, and is designed to operate in a particular sea area.

In recent years, a number of new types and designs of fixed offshore platforms have been proposed and implemented in response to the extensive development of offshore oil fields

Received: 20-01-2018
Approved: 10-03-2018

in various parts of the world's oceans. These types are distinguished by type of construction, method of support and fixing to the seabed, by material.

By design fixed offshore platforms are divided into rigid (gravity-based, piled-gravity, pile-supported) and elastic (guyed towers, floating towers, flexible towers), which reflects the design features of the platform and its flexibility characterized by a period of natural oscillations. On rigid platforms it is 4-6 s, and elastic - 20-100 s [3].

Rigid structures are classified according to the method of ensuring their stability under the influence of external loads into gravity-based, piled-gravity, pile-supported ones. In the first case, the structure does not shift relatively to the seabed due to its own mass, in the second case it does not shift due to the fastening of its piles [9]. Gravity-pile structures do not move due to its own weight and the piling system.

Elastic structures are divided by method of support into guyed towers, floating towers, flexible towers. Guyed towers retain their stability by a system of guy lines, pontoons of buoyancy and counterbalances. Floating towers are similar to a swinging pendulum, they return to a state of equilibrium with the help of pontoons of buoyancy located in the upper part of the structure. Flexible towers deviate from the vertical under the action of waves, but they, like a compressed spring, tend to return to equilibrium [12,13].

The structures of fixed offshore platforms can be attributed to the 1st group of structures by SNiP (Construction norms and specifications) for which steel classes C255, C285, C345... C440 should be used according to GOST 27772-88(National State Standart) with additional requirements for corrosion resistance (with copper). The use of thick-sheet steel in fixed offshore platforms structures (the thickness of the wall of the supporting trunk of piles can reach 90 mm) causes additional requirements for continuity and for the characteristics of steel across the rolled product[3].

6. SUMMARY

Designs of fixed offshore platforms are calculated by two groups of limiting states. By the first group of limiting states the following calculations are carried out: general strength and stability of the system; strength of individual elements, destruction of which leads to impossibility of operation of the facility; calculations of displacements of structures that affect the strength or stability of the structure as a whole etc. By the second group there are carried out the calculations for limiting of movements and deformations, strength of

Received: 20-01-2018
Approved: 10-03-2018

individual elements of the structure, which are not considered by limiting states of the first group.

The calculation of the strength of welded without joint plates structural nodes of pipes is carried out in accordance with the requirements of ISCS 51.4-85 (Industry-Specific Construction Standards). Since fixed offshore platforms can be attributed to tower structures subjected to cyclic dynamic loads their structures need to be checked by calculation of endurance.

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Received: 20-01-2018
Approved: 10-03-2018

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Received: 20-01-2018
Approved: 10-03-2018