Stress-deformed state of the container with the presence of an displacement of the butt edges in the ring welded joint of the body

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Abstract. Capacitive equipment of oil refineries is widely used in the operation of technological units and plays one of the dominant roles, both in terms of metal consumption and the degree of use. Depending on the purpose, the required capacity of the stored product and constructive features, containers reach rather large overall dimensions, which creates certain difficulties in diagnosing the entire surface of the vessel. In the process of manufacturing and repairing the bodies of technological tanks, it is possible to form such a geometric defect as "displacement of the edges of the abutting elements" when welding cylindrical shells to each other by circular welded seams. In the presence of geometric defects of this type, additional stress concentrators are created in the areas of the presence of these defects, which may be a prerequisite for the transition of an object to the limiting state in a fairly short period of time from the action of increased pressures and temperatures. Also, the presence of displacement of the edges on the body of the capacitive apparatuses can have a negative effect on the stress-deformed state of the considered capacity as a whole and to the formation of dislocation zones of increased stresses. Therefore, the actual work is the study of the stress-deformed state of the container with the presence of a zone of displacement of the edges in the circumferential welded seam of the body from the viewpoint of the formation of zones of increased stress. This work evaluates the stress-deformed state of the capacitive apparatus under the influence of operating parameters with a different location of the edge displacement zone in the circumferential weld on the apparatus body.

1. Introduction
Currently, in view of the fact that a large number of technological equipment at oil refineries has already undergone its moral and physical wear, there is an acute question of its better assessment of the technical condition, taking into account various factors that reduce reliability and resource [1-5]. The constant impact of high pressures, temperatures and working mediums, as well as the presence of defects in the metal and structure, inevitably lead the apparatus to the exhaustion of the resource and the transition to the limiting state for a certain period of time. Taking into account the aging and degradation of the equipment metal, as well as the dominant damage mechanisms, diagnostic methods are assigned, the capacity of which are regulated by regulatory documents. But in some cases, this capacity is not enough to obtain a complete picture of the actual technical condition of the object under consideration. This is especially true for large-sized devices, such as, for example, large-diameter containers with a large
surface area, which is not always possible to control one hundred percent. The qualitative assessment of the technical condition of the equipment and the forecasting of the resource with the so-called "permissible defects" also cause certain difficulties. The norms of the "permissibility" of a defect are indicated in the normative and technical documentation and are usually regulated by its type and size, as well as by its location in the structure. The "permissible defects" include the displacement of the edges of the abutting elements. The amount of displacement, depending on the responsibility of the operated equipment, is indicated in the relevant standards, guidelines, safety rules, etc. However, the current methods for assessing the technical state of technological equipment do not take into account the effect of edge displacement on the stress-deformed state (SDS) of the entire apparatus as a whole and the formation of zones of high stress concentration as a result. To study problems in this area, it is advisable to use software systems that allow you to build a 3D model of an object and study the SDS of the constructed model, taking into account all deviations in accordance with the real object. Therefore, the actual work is the simulation of the stress-deformed state of a capacitive apparatus with a different location of the zone of displacement of the edges in a circular welded seam from the action of working loads in order to identify the values of maximum stresses and zones of their concentration.

2. The methodology of the research
To study the effect of displacement of the edges in the circumferential welds of the body of the technological vessel on the stress-deformed state of the vessel, taking into account the location of the technological fittings, a buffer vessel of one of the oil refineries was selected [6-10]. The material of the body, bottom and hatch is carbon steel of ordinary quality ST3SP. The material of the process fittings is carbon quality steel 20.

The technical parameters of the tank are as follows: design pressure $P_{\text{calc}} = 0.65$ MPa; design temperature $T_{\text{calc}} = 100^\circ$C; working medium - hydrocarbon gas; inner diameter $D = 2400$ mm; case wall thickness $S = 22$ mm; bottom wall thickness of the left $S = 24$ mm; bottom wall thickness of the right $S = 28$ mm; tank body length - 10000 mm.

The buffer tank is a horizontal welded vessel consisting of a cylindrical shell of the body, welded from separate cylindrical shells, bottoms, process fittings with overhead rings on fittings of larger diameter and mounted on saddle supports. The body of the buffer tank consists of 6 cylindrical shells welded together with circular welds. The buffer tank is designed to reduce gas pulsation.

In the process of research, the licensed software complex "KOMPAS-3D" with an integrated APM FEM system was used to solve engineering and research problems. At the first stage, a model of the buffer tank was built in the KOMPAS-3D program [11-15]. The 3D model of the buffer tank is shown in figure 1.

Then, using the APM FEM strength analysis system, which is included in the KOMPAS-3D software package, loads were applied such as: pressure and temperature; fasteners are installed.

![Figure 1. 3D model of the buffer tank. A, B, C, D, E - circumferential welds on the body of the buffer tank; 1,2,3,4,5,6 - numbers of cylindrical shells that make up the welded body of the buffer tank.](image)
Further, the displacements of the edges in each of the circumferential welds (A-E) of the welding of the adjacent shells of the buffer tank body were set according to two options:

- displacement of the edges of the abutting mating shells by 1 mm upward (the left shell relative to the right one);
- the displacement of the edges of the abutting mating shells by 1 mm downward (the left shell relative to the right one).

Variants of displacement of the edges of abutting mating shells on the body of the buffer tank are shown in figure 2 (a-b).

![Figure 2. Variants of displacement of the edges of abutting mating shells on the body of the buffer tank. a) displacement of the edges of abutting mating shells by 1 mm upward (left shell relative to the right one); b) - displacement of the edges of abutting mating shells by 1 mm downward (left shell relative to the right one).](image)

3. **The results of the research and its discussion**

For a comparative analysis, at the first stage of the research, a strength analysis and an assessment of the stress-deformed state of the buffer capacity were carried out at operational parameters without displacement of the edges in the abutting conjugated shells of the body. The results of calculating the stress-deformed state of the buffer capacity at operating parameters without displacement of the edges in the abutting mating shells of the body are shown in figure 3.

![Figure 3. The results of calculating the stress-deformed state of the buffer capacity at operational parameters without displacement of the edges in the abutting conjugate shells.](image)
Figure 3 shows that the maximum stresses are 200 MPa and are concentrated in the zone of the insert of the lower choke on the cylindrical shell No. 1. Stresses close to the maximum values are located in the zones of circular welded joints of the buffer tank. Moreover, the zone of increased stresses is most pronounced in the zone of welding of the right bottom to the shell due to the large difference in the thickness of the joined elements.

At the second stage, a strength analysis and an assessment of the stress-deformed state of the buffer capacity with the presence of a 1 mm displacement of the edges of abutting mating shells in the circumferential welds of the body in accordance with figures 1 and 2. The most obvious results obtained with the maximum values of the acting stresses are shown in figures 4-6.

**Figure 4.** The results of calculating the stress-deformed state of the buffer capacity at operational parameters with the displacement of the edges of butted mating shells No. 1 and No. 2 by 1 mm in the circular weld A. a) the results of calculating the stress-deformed state of the buffer capacity at operational parameters with the displacement of the edges of the abutting mating shells by 1 mm upwards (left shell No. 1 relative to the right shell No. 2) in the circular weld A; b) the results of calculating the stress-deformed state of the buffer capacity at operating parameters with the displacement of the edges of the abutting mating shells by 1 mm downward (left shell No. 1 relative to the right No. 2) in the circular weld A.
Figure 4 shows that the maximum stresses are also concentrated in the stub area of the lower choke on the cylindrical shell No. 1. Their value is already 550 MPa with the displacement of the edges of the shell No. 1 relative to the shell No. 2 by 1 mm upward, which is 2.75 more than the values of the maximum stresses in the buffer tank without displacement of the edges of the abutting shells. When the edges of shell No. 1 are displaced relative to shell No. 2 by 1 mm downward, the maximum stresses are already concentrated in the cut-in zone of the upper extreme to the bottom of the nozzle on the cylindrical shell No. 6. The maximum values are 450 MPa with the displacement of the edges of the shell No. 1 relative to the shell No. 2 by 1 mm downward, respectively, which is 1.78 times more than the values of the maximum stresses in the buffer tank without displacement of the edges of the abutting shells.

Figure 5. The results of calculating the stress-deformed state of the buffer capacity at operational parameters with the displacement of the edges of the abutting mating shells No. 4 and No. 5 by 1 mm in the circular weld D. a) the results of calculating the stress-deformed state of the buffer capacity at operational parameters with the displacement of the edges of the abutting mating shells by 1 mm upwards (left shell No. 4 relative to the right shell No. 5) in the circular weld D; b) the results of calculating the stress-deformed state of the buffer capacity at operating parameters with the displacement of the edges of the abutting mating shells by 1 mm downward (left shell No. 4 relative to the right shell No. 5) in the circular weld D.

Analyzing figure 5, it can be seen that the maximum stresses are already moving into the zone of the circumferential weld of the shell No. 6 welding to the right bottom. Their value is 400 MPa with displacement of the edges of shell No. 4 relative to shell No. 5 by 1 mm upward. When the edges of shell No. 4 are displaced relative to shell No. 5 by 1 mm downward, the maximum stresses arise in the
cut-in zone of the upper extreme to the bottom of the nozzle on the cylindrical shell No. 6 and amount to 375 MPa.

In order to reduce the maximum operating stresses in the buffer tank in the presence of displacement of the edges in the circumferential welded seam of butted mating shells of the body for the most negative variant, shown in figure 4a (when the edges of the butted mating shells are displaced by 1 mm upwards (left shell No. 1 relative to the right shell No. 2) in the circumferential weld A; maximum stresses are 550 MPa), a constructive decision was made to use a stiffening ring. A variant of welding the stiffening ring to the casing of the buffer tank from the inside at a distance of 2400 mm from the left edge of the cylindrical body was modeled in order to add additional stiffness. The stiffening ring is an angle 15 × 15 × 5 mm made of ordinary quality carbon steel ST3. Figure 6 shows the inner side of the buffer tank body in section with a welded stiffener ring.

![Figure 6. Inner side of the buffer tank body in section with welded stiffener ring.](image)

The results of calculating the stress-deformed state of a buffer tank with a stiffening ring on the inner side of the cylindrical body are shown in figure 6.

![Figure 7. Results of calculating the stress-deformed state of a buffer tank with a stiffening ring on the inner side of the cylindrical body.](image)

As can be seen from figure 7, the maximum stresses when using a stiffening ring are only 230 MPa, which is almost 2.4 times less than the maximum stresses without it.
4. Conclusion

Based on the results of the simulation of the stress-deformed state of the buffer tank with the presence of a 1 mm displacement of the edges of abutting mating shells in the circumferential welds of the body, the following conclusions can be drawn:

- it was found that the magnitude and zone of concentration of maximum stresses is influenced by the location of the zone of displacement of the edges of abutting mating shells with a size of 1 mm in various circumferential welds of the cylindrical body, as well as the direction of displacement (up or down). This point must be taken into account when developing a program for technical inspection of capacitive equipment with the presence of displacement of the edges of abutting elements by increasing the capacity of control of these zones by non-destructive methods;
- it was revealed that in order to reduce the maximum possible stresses in the capacitive equipment in the presence of a zone of displacement of the edges of abutting mating shells of 1 mm in the circumferential welds of the body, it is possible to use stiffening rings, the design dimensions of which and the location should be determined by modeling the stress-deformed state of the apparatus in question, taking into account its design and operational features.

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