1. Tank crashes
2. Classification of defects
3. Object researching
4. Imperfections
5. Numerical model
6. Calculation results
7. Conclusion

STRENGTHENING OF WALLS FOR CYLINDRICAL VERTICAL MIDDLE VOLUME STEEL TANKS WITH GEOMETRIC IMPERFECTION

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1. Tank crashes

2. Classification defects

3. Object researching

4. Imperfections

5. Numerical model

6. Calculation results

7. Conclusion

THE DIAGRAM OF CRASH TANK

A – corrosive wear;
B – local corrosion;
C – low temperature;
D – welding defects;
E – shape defect;
F – foundation defects, careen;
G – vacuum, pressure difference;
H – poor quality of the steel;
I – infringement of the rules of exploitation;
J – infringement of the project;
K – infringement of the rules of test;
L – secondary crash;
M – stress concentration;
N – locked-up stresses;
O – fire;
P – loss of plasticity
1. Tank crashes

2. Classification defects

3. Object researching

4. Imperfections

5. Numerical model

6. Calculation results

7. Conclusion

<table>
<thead>
<tr>
<th>Cause of crash</th>
<th>Tank number was crashed</th>
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Quantity of causes of crashes
### 1. Tank crashes

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### 2. Classification defects

### 3. Object researching

### 4. Imperfections

### 5. Numerical model

### 6. Calculation results

### 7. Conclusion

Quantity of causes of crashes
Besides, the local shape defects are not considered to be uncommon phenomenon. An industrial complex of 78 cylindrical tanks, designed for light oil products, has been considered. A great part of local geometric defects has been disclosed on the lowest strip. Generally, 286 defects have been detected, 106 of which had highest geometrical parameters in comparison with those limited by the standards:

- 41 dents and 3 bulges – on 420 m³ tank,
- 24 dents and 6 bulges – on 700-3350 m³ tank,
- 26 dents and 2 bulges – on 5000 m³ tank,
- 4 dents – on more than 5000 m³ tank.
The first classification of defects:

1. Visible surface open defects of structure;
2. Invisible internal defects of structure.

The second classification of defects:

1. Corrosion of structure due to aggressive environment;
2. Low grade of basic metals;
3. Low grade of welds;
4. Stress redistribution, additional strains due to the settlement of foundation, local buckling and so on;
5. Stress concentration.
The third classification of defects:

1. “Sharp” defect.
In most cases the cracks in a material is characterized by a sudden cross-section reduction which calls significant increase of stress in comparison with the nominal stress in the same place without the construction defect;

2. Geometric defects are local defects of structure geometry in compare with design geometry of structure.

   2.1 type;
   2.2 cause;
   2.3 appearance time;
   2.4 geometry;
   2.5 volume;
   2.6 disposition.
VIEWS OF THE EXAMINED TANK

a. Common view

b. Sags with smoothly transition to swells at mounting welded

c. Sags with smoothly transition to swells at mounting welded

d. Flatness of few sheets of walls
1. Tank crashes
2. Classification defects
3. Object researching
4. Imperfections
5. Numerical model
6. Calculation results
7. Conclusion

Sags with smoothly transition to swells

The example of “Sharper” local geometric defect
1. Tank crashes
2. Classification defects
3. Object researching
4. Imperfections
5. Numerical model
6. Calculation results
7. Conclusion

LAYOUT OF TANK WALL $0^0 - 180^0$ WITH IMPERFECTIONS
1. Tank crashes

2. Classification defects

3. Object researching

4. Imperfections

5. Numerical model

6. Calculation results

7. Conclusion

LAYOUT OF TANK WALL 180° - 360° WITH IMPERFECTIONS
3D LAYOUT OF TANK WALL WITH IMPERFECTIONS
The shell geometry deviation at 2.4 m height above the bottom is

\[ \Delta = \frac{d_{\text{max}} - d_{\text{min}}}{d_{\text{nom}}} \]

\[ H = 2.4 \text{ m} \]

\[ \Delta = 0.007 \]
The shell geometry deviations at 7.5m and 15.0m height above the bottom are...
PARAMETERS IMPERFECTION

- depth of dent;

- depth of camber;

- radius of dent (camber). Smallest distance between point of ages of dent (of camber);

- radius of tank;

- relative depth of dent (camber);

\[ \gamma(f, t) = \frac{f}{t} \]

- relative radius of dent (camber);

\[ \beta(r, R, t) = \frac{r}{\sqrt{R t}} \]

- depth of dent (camber) in percentage from radius of dent (camber);

\[ % \]
### TANK WALL IMPERFECTIONS

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<th>f</th>
<th>r</th>
<th>t</th>
<th>R</th>
<th>γ</th>
<th>β</th>
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| | | A
| | | $f \leq 0.6\%$
| | | B
| | | $f \leq 1.0\%$
| | | C
| | | $f \leq 1.6\%$
| | | API STANDARD 650
| | | Welded Steel Tanks for Oil Storage
| | | $f \leq 1.4\%$
| | | CTO 0030 – 2004
| | | $f \leq 1.0\%$
| | | DIN 18800
| | | $f \leq 1.0\%$
| **semi-sphere** | **truncated cone** | **cone** |
NUMERICAL MODEL

1. Tank crashes
2. Classification defects
3. Object researching
4. Imperfections
5. Numerical model
6. Calculation results
7. Conclusion

Discrete model of tank (a);
Reguler geometrical model (b);
Geometrical model with imperfections (c).
CALCULATION RESULTS

Diagram of circumferential stresses on wall surface of tank when tank is filled (a); Diagram of pressure of stored product (b); Values of stresses (c)

\[ \sigma_y = 204 \text{MPa} < f_y = 255 \text{MPa}. \]
Diagram of von Mises stresses on wall surface of tank when tank is filled (a, b); values of stresses (c)
CALCULATION RESULTS

\[ \sigma_y = 273.5 \text{MPa} > f_y = 255 \text{MPa}. \]

Diagram of circumferential stresses on wall surface of tank when tank is filled (a); diagram of pressure of stored product (b); values of stresses (c).
Stress concentration factor at the point "b" is equal to:

\[ k_{\sigma,b} = \frac{\sigma_{k,b}}{\sigma_{nom}} = \frac{273.5}{204.0} = 1.34 \]

Stress concentration factor at the point "a" is:

\[ k_{\sigma,a} = \frac{\sigma_{k,a}}{\sigma_{nom}} = \frac{273.5}{183.5} = 1.49 \]
CALCULATION RESULTS

First case of reinforcement of wall (a); diagram of von Mises stresses and values stresses (b)
1. Tank crashes
2. Classification defects
3. Object researching
4. Imperfections
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7. Conclusion

**CALCULATION RESULTS**

\[ \sigma_y = 249.7 \text{MPa} < f_y = 255 \text{MPa}. \]

Second case of reinforcement of wall (a); Diagram of von Mises stresses and values stresses (b)
CONCLUSION

1. Factor of stress concentration takes the leading position, (position 6), between the reasons of tanks fracture. On the other hand the deviation of tank geometry and smooth local defects make secondary influence to load bearing capacity of the shell structures.

2. If the distance between defects is small it should be examined their group not a single defect.

3. Smaller single defects have clear location zones of stress concentration – circumference of defect and its inner zone.

4. In order to effectively reduce the stress concentration the strengthening elements should be located in the places with largest stress.