

## Removing of existing vertical joints in the shells of steel vertical tanks, which are executed as lap, welded joints and their new execution as butt joint with full penetration and fusion

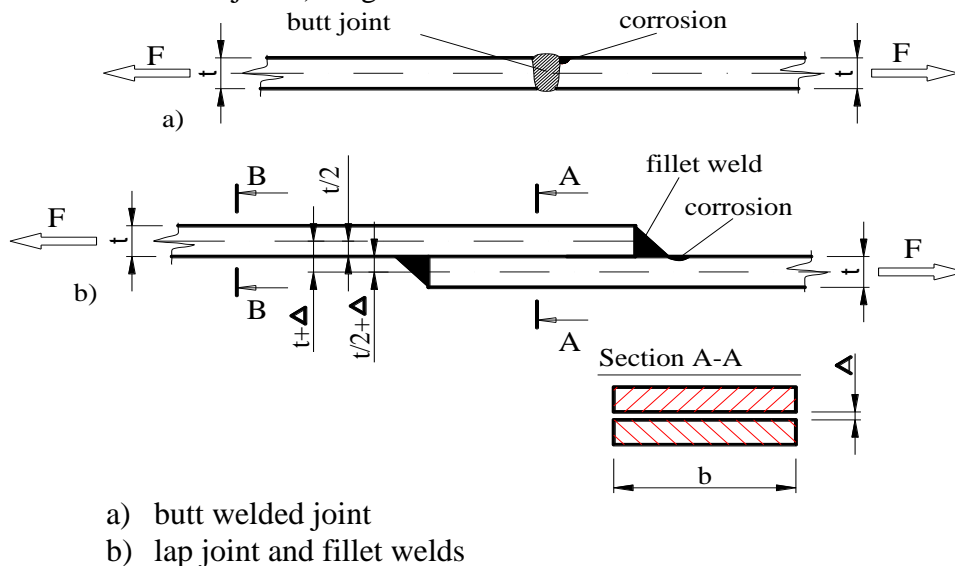
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Big part of the vertical joints made on the site of tanks in Bulgaria, which shells are executed as rolls in factory, are made as lap weld. This fact contradicts with the requirement that vertical welded shell's joints of tanks must be executed as butt joint with full penetration and fusion. It is necessary that tank repairing works include replacement of executed as lap joints and bilateral fillet welds of the shells.

When there are an erected shield roof and good quality of executed lap joint there, it is not necessary that the repairing works include the upper courses which have the minimum thickness and it is not result of calculations.

The effort of lower courses grows considerably and the joints in courses must be executed as butt joints in order to eliminate the complementary tensions, which are a result of geometrical defects of lap joints and the bends which are the consequence of it.

We will survey the corrosion under tension, which appears in the welded joints (butt joints and lap joints and bilateral fillet welded joints) - fig. 1.



**Fig.1.** Corrosion under tension in welded joints

For different sections, provided the linear condition of the problem the following values of tensions are calculated:

**For section A-A:**

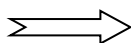
$$\sigma = \frac{F}{A} + \frac{M}{W}$$

$$M = F.t$$

$\Delta = 0$  - distance between sheets

$$A = 2.b.t$$

$$W = \frac{2}{3}.b.t^2$$



$$\sigma = \frac{F}{2.b.t} + \frac{F.t}{\frac{2}{3}.b.t^2} = \frac{F}{b.t} \quad (1)$$

$$\sigma = \frac{F}{A} + \frac{M}{W}$$

$$\Delta \neq 0$$

$$M = F \cdot (t + \Delta)$$

$$A = 2 \cdot b \cdot t$$

$$W = \frac{1}{6} \cdot [b \cdot t^2 + 3 \cdot b \cdot (t + \Delta)^2]$$

$$\Rightarrow \sigma = \frac{F}{2 \cdot b \cdot t} + \frac{6 \cdot F \cdot (t + \Delta)}{[b \cdot t^2 + 3 \cdot b \cdot (t + \Delta)^2]} \quad (2)$$

**Section B-B**

$$\sigma = \frac{F}{A} + \frac{M}{W}$$

$$M = F \cdot t$$

$$A = b \cdot t$$

$$W = \frac{1}{6} \cdot b \cdot t^2$$

$$\Delta = 0 \text{ - distance between sheets}$$

$$\Rightarrow \sigma = \frac{F}{b \cdot t} + \frac{6 \cdot F \cdot t}{b \cdot t^2} = \frac{7 \cdot F}{b \cdot t} \quad (3)$$

$$\sigma = \frac{F}{A} + \frac{M}{W}$$

$$M = F \cdot (t + \Delta)$$

$$A = b \cdot t$$

$$W = \frac{1}{6} \cdot b \cdot t^2$$

$$\Delta \neq 0 \text{ - distance between sheets}$$

$$\Rightarrow \sigma = \frac{F}{b \cdot t} + \frac{6 \cdot F \cdot (t + \Delta)}{b \cdot t^2} \quad (4)$$

**Section C-C – situated at a big distance from the overlap of sheets.**

$$\sigma = \frac{F}{A} = \frac{F}{b \cdot t}$$

Provided the linear geometric condition of the problem, without registering the bending of sections and when there is not distance between sheets ( $\Delta = 0$ ), the calculated values of the tensions are the following:

- the tension in the part of the lap joint ( section A-A) are equal to tensions in part of shell situated in a sufficient distance of the shell (section C-C);
- the tensions in the section close to the part of lap joints (section B-B) are 7 times more than the tensions in section C-C;

If there are some distance there between the jointed sheets ( $\Delta \neq 0$ ), the tensions increase in the part of lap welded joint and the neighboring, nearly situated parts.

For examination behavior of weld joint, executed as lap joint, eng. Zdravkov created an computer model of it and solved many times through computer software **ANSYS** in order to avoid possible mistakes in reporting the results. Finally the results were treated statistically.

The survey for determining tensions and joint was carried out on the following conditions:

- a) the sheets of steel shell have the following characteristics:
  - Yield strength  $R_{yn} = 200 \div 375$  MPa;
  - Modulus of Elasticity  $E = 2,1 \cdot 10^8$  kPa;
  - Coefficient of Poisson  $\nu = 0,3$ ;

b) the values for the tensile stress in the sheets  $\sigma_2$  used for this survey are proportionate to the yield strength  $R_{yn}$  as used tensions  $\sigma_2 \approx 0,25.R_{yn}$

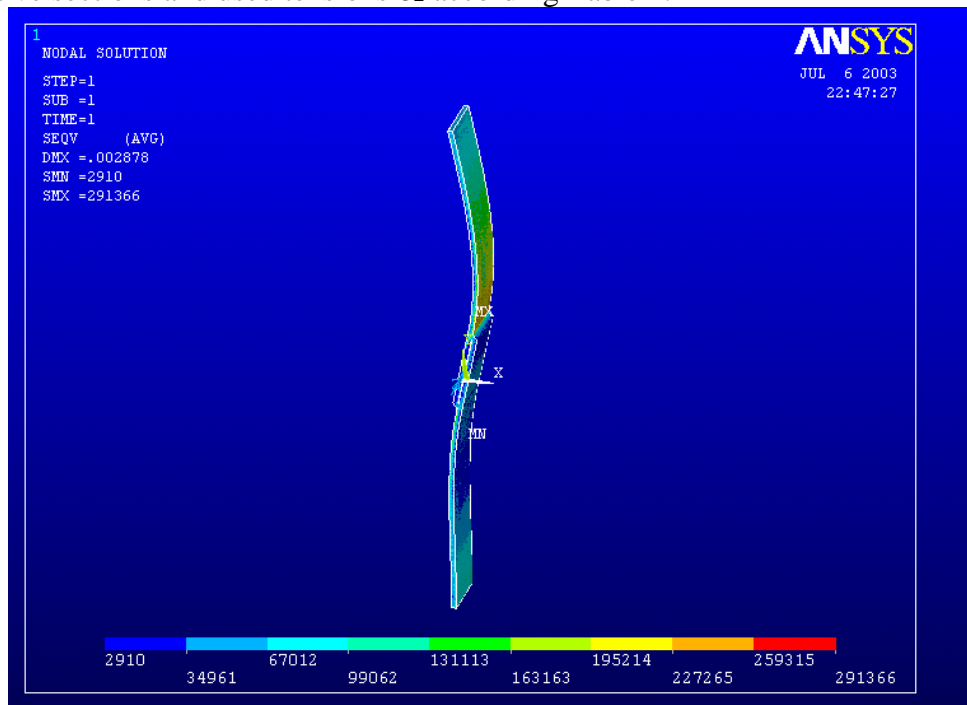
**Table 1**

|                  |     |     |     |     |     |     |     |     |
|------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| $R_{yn}$ , MPa   | 200 | 225 | 250 | 275 | 300 | 325 | 350 | 375 |
| $\sigma_2$ , MPa | 50  | 57  | 63  | 69  | 75  | 82  | 88  | 94  |

- c) the overlap of the sheets vary between 30 ÷ 100mm, with 10 mm step every variation;
- d) thickness of the sheets  $t_s = 4 \div 6$  mm;
- e) distance between sheets  $\Delta = 0,5$  mm.

Analysis of the received results:

When the basic conditions of the problem are not linear, the calculated tensions are very different from the results theoretically calculated from linear basic conditions of the problem. Due to bending of sections of the joint (fig. 2), tensions considerably diminish. The calculated excess (in times) is shown for different sections for joint (Table 2). The excess is the relation between the calculated main tensions  $\sigma_{red}$  in respective sections and used tensions  $\sigma_2$  according Table 2.



**Fig. 2** Bending of the sections in lap welded joints

**Table 2**

| Section of joint executed as lap welded joint                     | In the section situated far from lap joint | In the middle of lap joint | In the weld | In the place of joint shell - joint | In the shell next to joint | In the shell at $\approx 70$ mm from welds | In the shell at $\approx 140$ mm from welds |
|---|--|----------------------------|-------------|-------------------------------------|----------------------------|--|---|
| Excess in the calculated tensions $\sigma_{red} / \sigma_2$ times | 1  | 0,6636                     | 3,6385      | 3,883                               | 3,9198                     | 3,8145                                     | 2,9735                                      |

Table 2 shows that the biggest excess of tensions corresponds to the following conditions:

- (5)  $\sigma_{red} \approx 4.\sigma_2$   
 $\sigma_{red} < 4.\sigma_2$

According to research of welded joints, made as lap joint and bilateral fillet welds, the maximum hoop tensions  $\sigma_2$  in the sheets of the shell, which are jointed as lap welded joints must meet the following condition:

$$(6) \quad \sigma_2 \leq \gamma_c \cdot R_y$$

where:

$\sigma_2$  – hoop tension in tank shell

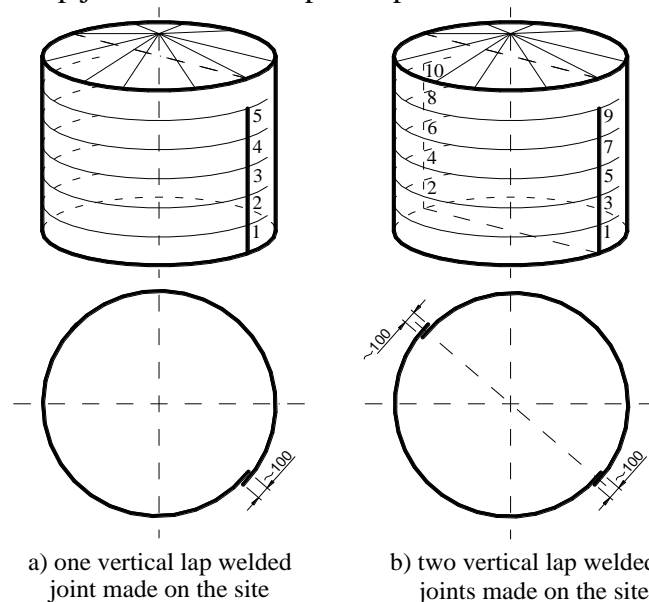
$\gamma_c = 0,25$  - coefficient of condition of work of joint made as lap joint:

$R_y$  – border resistance of yield strength of steel in shell

The developing corrosion under tension is ascertained as main reason for accident with condensate tank with  $V = 2000 \text{ m}^3$  capacity in Thermal Power Plant “Maritza – Iztok III”

The technological continuity when the repairing works have been executed as follow:

- a. vertical lap welded joint, made on the site, must be divided into parts, and the repairing works must begin from first shell course;
- b. the part of lap welded joint, made on the site, must be prepared, repaired and controlled;
- c. after finishing and inspection of this part of the joint, the operation must be repeated above:
  - to the another vertical lap joint on the shell, if the lap joints are more then one;
  - to the same vertical lap joint above the repaired part.



**Fig. 3.** Location and scope of the repairing work of the vertical lap joints made on the site

The size of one part from the shell where the vertical lap joint will be removed at once, and the butt joint which will be executed in order to replace the previous one, must not exceed the following values:

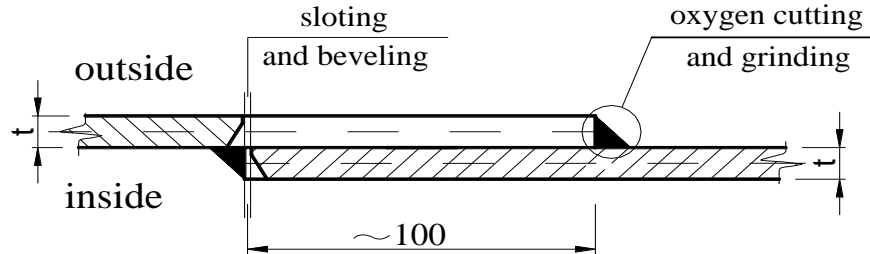
- a. the length of the part can not be more than 3m;
- b. the part can not include two shell courses at once;
- c. the length of the part can not exceed 1/3 from the full height of the tank shell.

#### Preparing works

The preparing works of every erected joint and for every part of the above mentioned joint by its height include (fig. 4):

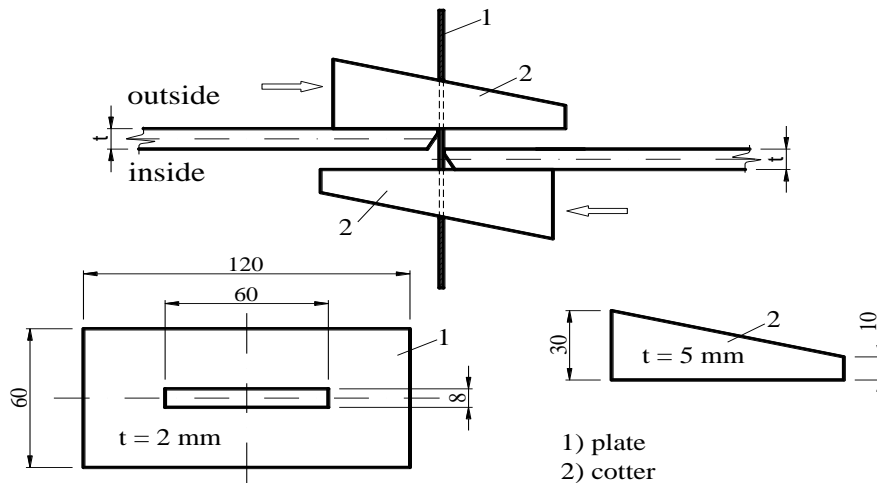
- oxygen cutting of the insider weld of lap joint from the top to the bottom in the border of the part;
- cutting of the shell in the opposite side of the insider weld of lap joint from the top to the bottom in the border of the part;

- beveling of the ends which must be made the inside. This operation will provide more correctness of the geometrical form during the welding;
- roughly (approximately) and precisely opposite meeting of the prepared for joint ends;
- fixing the edges through single short welds from the inside part and putting of the bracket with supporting traverse if it is necessary to improve the geometry of the shell;
- execution of new butt joint, made on the site.



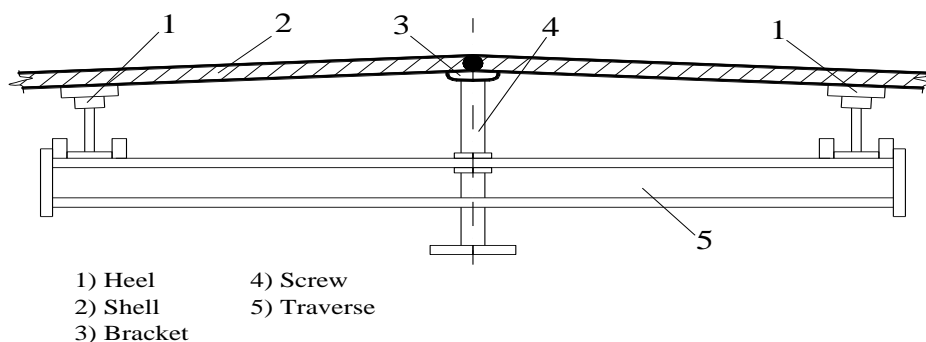
**Fig. 4.** Primary preparation to change the existing vertical lap joint to butt welded joint in the shell

Precisely opposite fixing (meeting) of the edges of erected plates can be made by means of flat plates and bilateral flat cotters.



**Fig.5.** Precisely fixing of the ends of the rolled shell

When after the removing of the lap joints the part near to the vertical joints sink to the inside (“sea – full”), the above mentioned part must be curved to outside till the protrusion from 5 ÷ 10 mm. The preparing of the vertical joint for approximately opposite fixing of the edges and for removing of the “sea-full” can be done by means of screw bracket with support traverse ( fig. 6 ).



**Fig. 6** Screw bracket with traverse

After the visual check up of the axes of the ends, the edges should be fixed by means of welding from the inside at distance of 200 ÷ 300 mm. At approximately the same distance must be fixed the brackets with traverse.

The repairing works

The real repairing works of the joints includes welding of the new vertical butt joints.

The welding of the new butt joint must be done after check up the quality and the correctness of the preparing works.

In order to decrease the risk of defects during the welding of every prepared part the following technological sequence must be respected:

- the number of layers of the welded joint depends on thickness of shell;
- the welding must be executed according to reverse step method - the general direction of to increase from the top the bottom, with the direction of the grades from the bottom to the top.

The special attention must be paid to the welded joints, forming the beginning and the end of all made on the site joints – their connection with periphery zone in the bottom and with erected joint in the last course (if any).