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INFLUENCE OF VIBRATIONAL TREATMENT ON QUALITY OF WELDING JOINTS OF VERTICAL STEEL TANKS

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Abstract: This article deals with vibration treatment during welding process as a way of increasing the accuracy of the geometric shape in the vertical butt joint area and corner weld joint when installing vertical steel tanks from rolls. The rolling method is the most promising and worthwhile method of vertical steel tanks manufacturing. However, during the installation process defect like angularity in vertical butt joint is occurred because of residual welding deformations. Another problem of installation of tanks is the lack of penetration in the T-joint in corner weld joint. Both of these defects influence on fatigue durability of the welded construction of tanks. Article discusses the influence of vibration treatment on form of welded joints and level of welding deformations of steel plates. Also parameters of vibration treatment were searched which allow to obtain the best effect of reducing of welding deformations: modes without vibration treatment, with vibration treatment with constant amplitude and vibration treatment with amplitude-modulated signal were considered.

Keywords: rolling method, tank, welding deformations, angularity, lack of penetration, vibration treatment, amplitude modulation.

1. Introduction

In modern conditions of manufacturing the most promising method of manufacturing of vertical steel tanks developed in USSR in 40s of the last century is the rolling method in which the main constructive elements assembly operation of the tank are manufactured at the factory and delivered to job site as a rolled welded panels. The main advantage of this method compared to the sheet assembly is the reduction amount of welding operations at the job site by approximately 80%. Moreover, high quality of welded joints, ensuring be application of double sided automatic welding at the factory allowed this method of manufacturing of tanks to be widely used.

However during structural fabrication there are difficulties emerge in obtaining designed shape of the wall in the vertical field joint and also insufficient straightening end area of panels before edges closure operation combined with a welding deformation which lead to such a defect as the weld angularity. The bending deflection$f$ in the entering of inner wall from the designed generator line of tank is taken as the coefficient of angularity.

Today there are several solutions to get joints with the permitted angular deformity. In practice this problem is partially solved either mechanically (welding "tooth" field joint, cropping deformed sections with subsequent welding of special inserts, upheaval buckling of edges before welding operations), or using special welding processes provided the project of works: welding short sections, a certain stacking order of weld seams [1,2]. In the process of assembly it is often impossible to predict how welding operations influence on angularity of the vertical joint.

Operational experience of vertical steel tanks and experimental studies carried out at the Institute of Electric Welding named after Paton E.O. showed that the angular displacement in welded joints under low-cycle loading leads to a sharp fall of performability of edge joints with the emergence of fatigue cracks [1].

Another problem in installation of vertical steel tanks related to the fact that according to [3] the T-joint with constructive the gap within 2 mm is used during connection of tank shell with the bottom (Fig. 1). In addition to the above for tanks with the plate thickness of apron ring20 mm or less weld joint without edge preparation is recommended. It was established [4] that the width of lack of penetration *d* through-the-thickness *t*, the amount of which is not regulated by any normative document, has an affect on operational life of the T-joint: increase in width of the lack of penetration to 5 mm leads to decrease in fatigue strength for 13-14%.

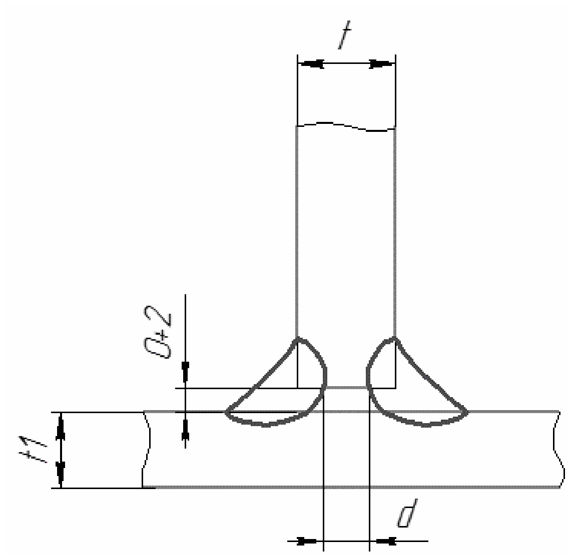


Fig.1. Welding joint of bottom and tank shell with thickness up to 20 mm

Thus the need arises for measuring the level of welding stresses and deformations in the area of field joint of vertical tanks and the development of effective measures to reduce them, as well as searching ways to reduce the lack of penetration during welding assembly of tanks.

This paper deals with the influence of vibration treatment during welding cycle on geometry of welding joints and the level of residual strains.

Based on analysis of literary sources it is to be noted that the amplitude of low- frequency vibrations *c* up to 1 mm applied transversally in the vertical plane and in orthogonalaxicon of the weld seam positively influences on crystallisation process of weld-seam metal also milled and ordering its microstructure.

Furthermore, the vibration oscillation of the weld pool sets the temperature balance within the crystal lattice and reduces proportion of gas pockets [5].

2. Experimental conditions

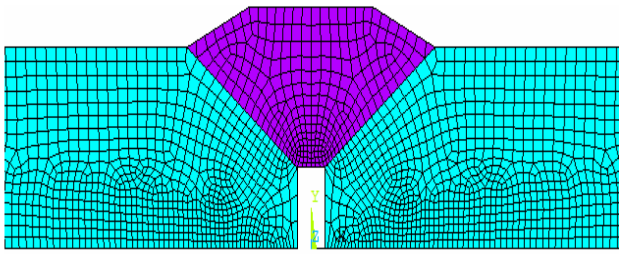
In experiments sizes and shapes of weld pool were compared in the cross-sectional view obtained by butt welding with an accompanying vibrational treatment and without it in the following modes:

- wire diameter 1,2 mm;
- arc welding current I = 225-231 A;
- voltage U = 28-30 V;
- wire feed speed Vpp = 56-58 m / h.

It is found that application of vibration treatment leads to deep penetration and the weld width seam is less than seam after welding in normal conditions. Such a form of weld is more correct in terms of residual welding deformations. Abovementioned is verified by calculations carried out in ANSYS by finite-element method.

3. Simulation

At stage of simulation geometric models with butt-joined seam with different relative depth of penetration *h / s* (the ratio of height to the thickness of seam plate) were built in ANSYS software environment (Fig. 2).



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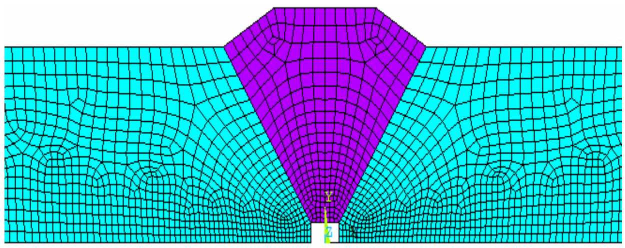


b

a – h/s=0,6; b – h/s =0,9

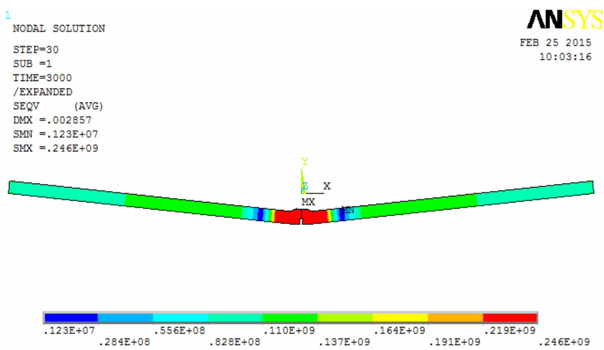
Fig. 2. Shape of welding joint

The problem of determining the stress-strain state of construction in ANSYS reduces to the solution of thermal and mechanical problems considering plastic strain and material creep.

The cooling process of model in field joint area under natural convection has been set in solving the temperature problem.

Finite element PLANE77 was used wherein the thermophysical properties of material such as the heat capacity, thermal conductivity, thermal-expansion coefficient were given as variables depending on the temperature. It has allowed to improve accuracy of results obtained. The convection heat transfer from outer surface was applied as a boundary conditions.

At the stage of structural task solution,the element type was changed to the relevant finite element PLANE183 with mechanical properties, also elastic and plastic properties of material were given. Reading of results of thermal analysis and the application of temperature fields in structural elements in the form of load is carried out. The restraint of displacement are applied as a boundary condition. Results of solution figures of equivalent residual and angular strain were obtained (Fig. 3). Determination results of deformations as angularity of welded constructions models with various depth of penetration are shown by dependence in fig. 4.



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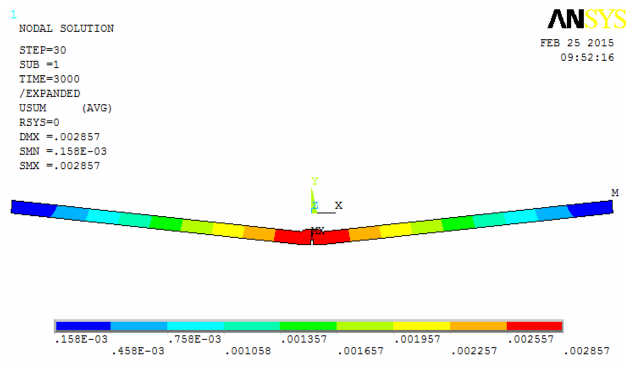


b

a – equivalent stresses, b - strains

Fig. 3. Stress-strain state of sample (*h/s* =0,9)

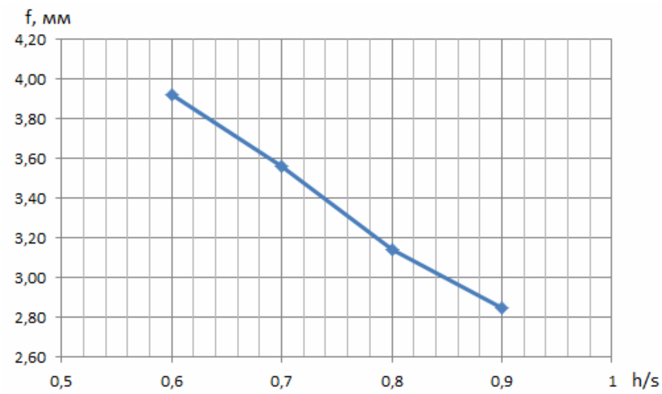
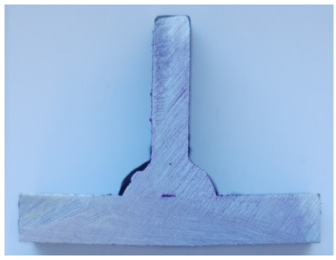


Fig. 4. Dependence of angularity on the relative depth of penetration

4. Experimental results

Experiments were performed with T-joints samples, which are applied for connection of the tank bottom with a wall. Welding was performed under the same modes.

Experiments showed that application of vibration treatment during T-welding significantly reduces the lack of penetration (Fig. 5).



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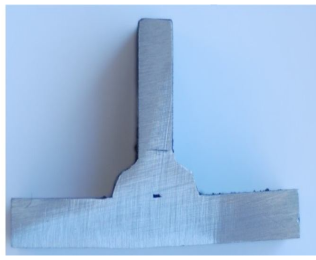
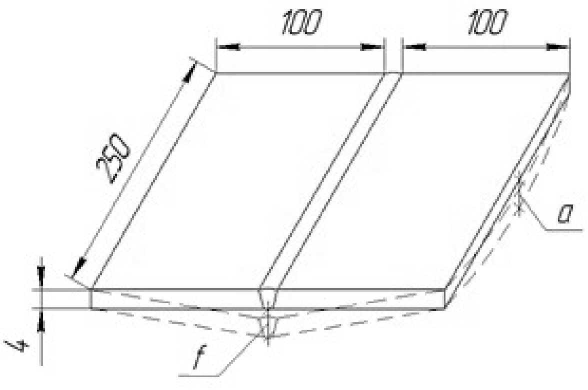


b

a – without vibration treatment; b – with vibration treatment;

Fig. 5. Pictures of samples after welding

Further, as a part of the study; various modes of accompanying vibration treatment were compared for finding the one to achieve the best effect of decrease in residual deformations. Experiments when butt-welding of plates from steel 09G2S with 4 mm thick were performed (Fig. 6), thereby the modes without vibration, with vibration treatment with constant amplitude and with vibration treatment with amplitude-modulated signal (Fig. 7, table 1) were considered.



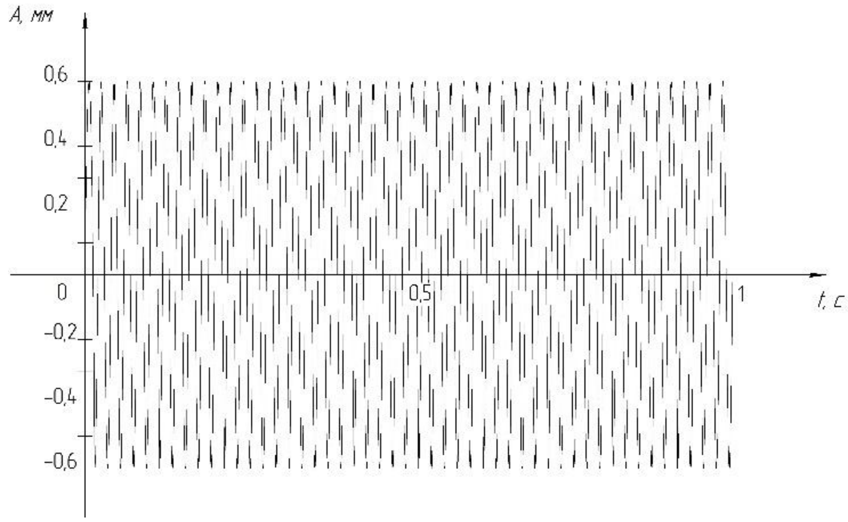
a – bending deflection; *f*- angularity
Fig. 6. Sample design

In this latter case (amplitude-modulated signal) oscillatory motion is possible to describe by equation 1

$$A=0,17\cdot[1+0,566\cos(2\pi\cdot t)]\cdot\cos(100\pi\cdot t), \quad (1)$$

whereA - range of vibrations, mm;
t – time, c.

Experiments were performed on vibration stand "VEDS-400", amplitude modulation was implemented by vibration change in the limit of 5..25 m/c^2, in such case carrier vibration frequency was accepted 50 Hz, and modulating frequency was established on 1 Hz.



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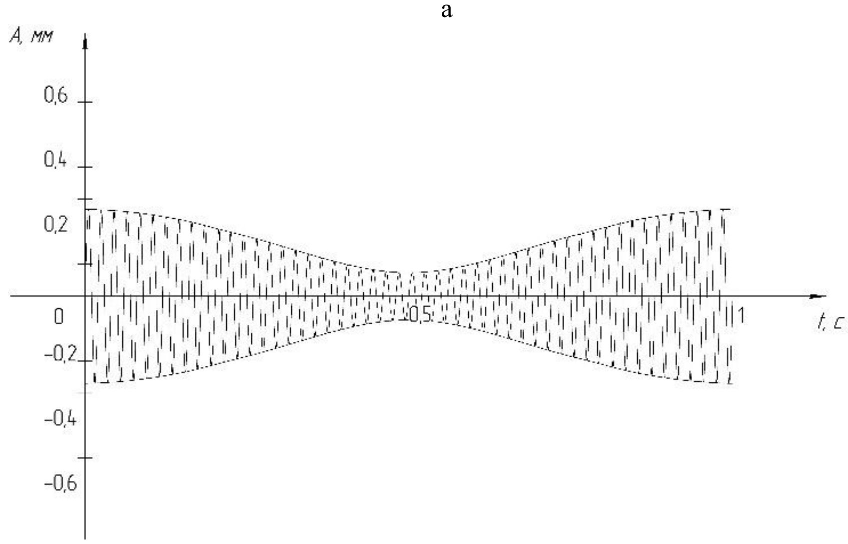

b

a – with constant amplitude; b – with amplitude modulation
Fig. 7. Oscillatory motion

Table 1

Process conditions of samples

Machining-conditions	Vibration-frequency, Hz	Vibration-amplitude, mm	Vibration-acceleration, m/c^2
Without vibration	–	–	–
With vibration on constant amplitude	50	0,6 – 0,8	5
With vibration on amplitude modulation	- carrier – 50, - modulate – 1	0,073 – 0,265	5 – 25

The constructed graph based on obtained results of deviation measurements is shown in fig. 8.

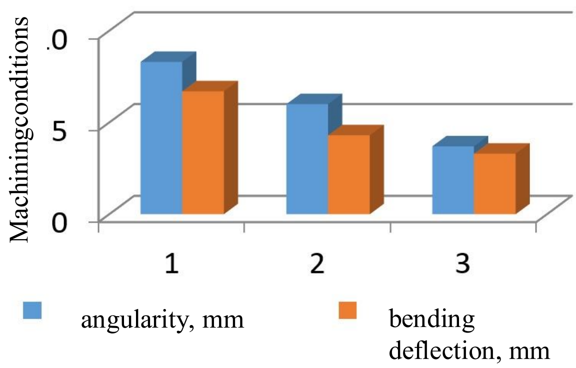

Fig. 8. Samples deformation at various process conditions

Diagram shows that vibration treatment with amplitude-modulated signal is followed with minimal residual deformation both in the longitudinal and the transverse direction.

4. Conclusions

Thus, researches showed that accompanying vibration treatment during welding of workpieces made of steel 09G2S:

- increases the depth of penetration in butt joint workpieces that causes less residual strains;
- allows to reduce value of lack of penetration in T-joints, thereby increasing resource of operational capability of construction;
- is effective in terms of decreasing residual welding deformations as a angularity and deflection along the sample using the amplitude-modulated signal with the amplitude up 0,073 mm to 0,265 mm.

Obtained results are possible to consider in the planning of activities to improve the accuracy of geometric shape in the field joint and T-joint during installation of vertical steel tanks from rolls.

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