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Features of welding using integrated protection environment

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Summary. This article presents the results of experimental studies on welding in a complex protection environment (CPE). There are presented peculiarities of welding in the lower and in the ceiling spatial position. Application possibilities of welding using CPE in the regional enterprises are also presented
Key words: welding, complex protection environment, welding deformation.

INTRODUCTION

Currently, about 30% of the machinery industry production are welded constructions of metal with the thickness from 2 mm to 6 mm [3, 21, 23], such as railway cars, containers for transportation of bulk cargo [4], evaporators, liquid separators, absorbers, filters, heat exchangers, distillation columns, etc. In the manufacture, volume of such welding structures reaches 70%, which leads to a more expensive product [14, 27, 30]. One way to reduce the final cost of welded products is the use of resource-saving technologies [15, 24, 25, 28, 29] and reduce the consumables cost [1, 16, 18, 19, 26].

ANALYSIS OF PUBLICATIONS, MATERIALS, METHODS

The most widely used method is arc welding, because of its ease of implementation, a high concentration of thermal energy, reliability, welds stability characteristics comparative simplicity of mechanization [12, 22].

The most promising is the use of resource-saving technologies in welding, modifying and combining of existing technologies, the choice of the least energy-intensive methods of welding Fig. 1.

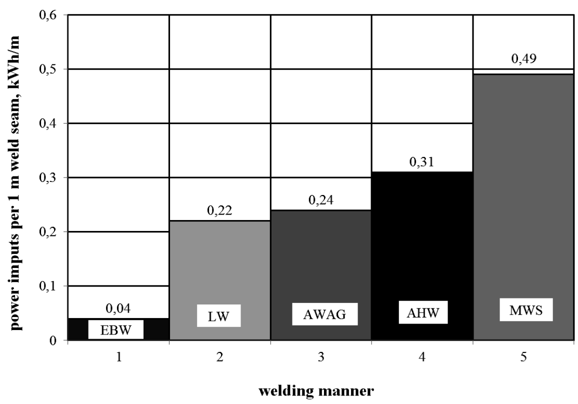

Fig. 1. Cost sharing of electrical energy per 1 m of weld of the connection C4 for various ways of the welding: EBW – electron-beam welding, LW – laser welding, AWAG – automatic arc welding in active gases, AHW – automatic hidden arc welding, MWS – manual arc welding

At the same time, it is necessary to develop and implement welding methods with minimal negative impact on the welder and the environment, use technology of effective capture [9, 10] and recycling or disposal of welding fumes.

The problems of resource-saving in welding, welding fume and aerosols capture, anti-ultraviolet radiation of the arc must be addressed comprehensively. One way of solving this is to use complex protection environment (CPE) in arc welding [2, 8].

THE PURPOSE AND MISSION STATEMENT OF THE RESEARCH

The aim of this work is to study the characteristics of the welding process using the CPE in different positions. To fulfill the purpose the following objectives have been stated: To investigate the characteristics of welding to the CPE in the down position, investigate the features of the CPE welding in the overhead position, to explore the possibility of using welding with the CPE in the enterprises of the region.

THE MAIN SECTION WITH THE RESULTS AND THEIR ANALYSIS

Depending on the relative position of the welded details, welded joints are divided into: butt, lap, tee, corner, face (side). All types of welded joints, their assembly and weld seam geometry is rigidly regulated by GOST 5264-80, GOST 16037-80, GOST 8713-79, GOST 14771-76, GOST 14776-79, GOST 11534-75, etc., and retreat from them is not valid.

Experimental studies were carried out on steel VSt.3ps (GOST 11474-76), the size of the welded plates is 300X200 mm, 5 mm thick. There was used welding wire Sv-08 (GOST 2246-70) with a diameter of 2.5 mm. Welding equipment: automatic ADS-1000-1 with the power supply VSU-300. For CPE there was used a dispersed generator developed by [5] (Fig. 2).

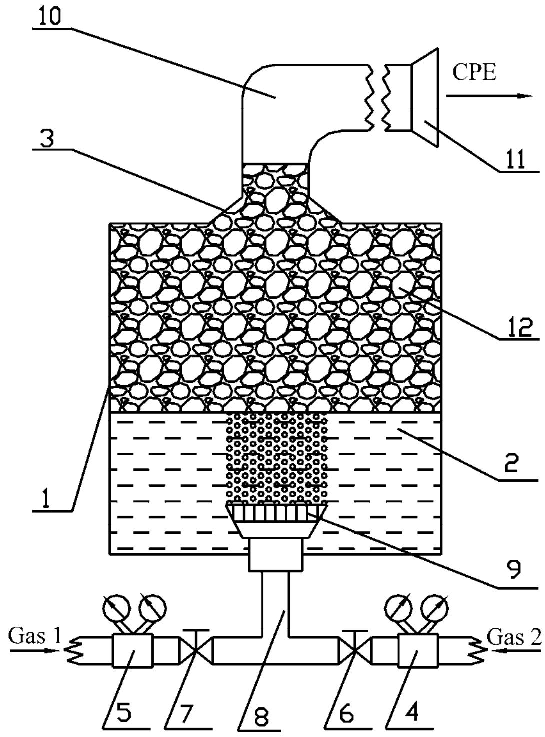

Fig. 2. The circuit of the generator for deriving CPE: 1 – the generator cage, 2 – a solute of superficially active substance, 3 – a fitting pipe, 4 and 5 – gas reducers, 6 and 7 – valves of adjusting of pressure of gas, 8 – handset for a gas intake, 9 – the gas breaker plate, 10 – a flexible tube for feeding CPE, 11 – a replaceable nozzle for feeding КЗС, 12 – CPE

The compositions of the CPE are under the identification numbers №1, №2, №3, №4, №5, №6 [7]. Welding mode: arc voltage U_a=30 V, welding current I_w=250 A, welding speed V_w=30 m/h.

The experimental results showed that the CPE welding can be carried out in all positions (the lower, vertical, horizontal and overhead). The main features of welding in different positions do not differ significantly from the classical concepts. However, there is a number of features associated with the use of the CPE.

The main feature of welding in CPE is the complexity of welded parts seam visual tracking. Insufficient supply of CPE results in penetration of the weld zone of atmospheric air and in defects in the form of pores.

Welding features using CPE lower position.

When welding using CPE lower position, it is necessary to take into account the complex forces acting on the molten metal droplet Fig. 3. According to researches [20], main forces are: the axial component of the electromagnetic force P_{em}, directed from a smaller to a larger section of the conductor, the force of gravity P, is directed downward, the strength of the surface tension P_σ, holding the drop of the electrode.

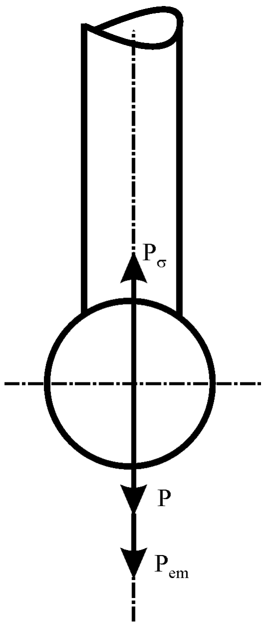

Fig. 3. Diagram of the forces acting on the molten metal droplet electrode for the lower spatial position welding

The strength of a jet of vapor pressure when welding on the reverse polarity is small and is not taken into account (exerts its effect in by welding on straight polarity).

The component of the electromagnetic force:

$$P_{em} = B \cdot I^2 \cdot \left(1 + 4.6 \cdot \lg \frac{r_c}{r_e}\right), \qquad (1)$$

where: P_{em} – the component of the electromagnetic force (N), B – aspect ratio (N/A^2), r_c and r_e – radius of the arc column and the electrode (m), I – the arc current (A).

The drops surface tension:

$$P_\sigma = \pi \cdot d_e \cdot \sigma, \qquad (2)$$

where: P_σ – the drops surface tension (N), d_e – electrode diameter (m), σ – The surface tension of the drop metal at the edge of "drop-electrode" (N/m).

The force of gravity for the drop:

$$P = \frac{4}{3}\pi \cdot R^3 \cdot \gamma \cdot g, \qquad (3)$$

where: P – the force of gravity for the drop (N), R – drop radius (m), γ – density of the liquid steel (kg/m^3), g – acceleration of free fall (m/s^2).

The condition for a tear drop is:

$$P_{em} + P \geq P_\sigma. \qquad (4)$$

When welding in the CPE, the following values are included in the formula (Eq. 1–3): $B=5 \cdot 10^{-8}$ (N/A^2), $r_c=1.1 \cdot 10^{-3}$ (m), $r_e=0.8 \cdot 10^{-3}$ (m), $d_e=1.6 \cdot 10^{-3}$ (м), $\sigma=1.22$ (N/m), $R=1.8 \cdot 10^{-3}$ (m), $\gamma=7 \cdot 10^3$ (kg/m^3), $g=9.8$ (m/s^2).

After substituting the values of (Eq. 1–4), we obtain:

$$6.18 \cdot 10^{-3} + 0.97 \cdot 10^{-3} > 6.13 \cdot 10^{-3},$$

i.e. tear drop condition is satisfied.

Welding features using CPE overhead position.

A similar (Eq. 4) calculation can be made for different spatial positions and determine the possibility of electrode metal transfer into the weld pool for subsequent adjustment of welding modes.

For example, the condition (Eq. 4) in the case of ceiling seams welding becomes:

$$P_{em} \geq P_\sigma + P. \qquad (5)$$

After substituting the values in the formula, it can be seen that the condition of tear drops is not fulfilled, that is, transfer of electrode metal is complicated.

From the analysis of (Eq. 1-3) it can be seen that on the transfer of electrode metal into the weld pool greatest effect is made by current (quadratic dependence). However, the ability to control the metal transfer by changing the value of welding current , in most cases depleted, as evidenced by welding methods with forced transport of the metal electrode overlapping the mechanical vibration to the electrode and the electric pulse welding. In our opinion there is an additional opportunity to improve the transfer of welding droplets by changing the surface tension of the drop. In the given example (the remaining conditions being unchanged) σ value must be reduced to a value of 1.037, then tear drop condition (Eq. 5) is satisfied. Reduction of σ can be achieved, for example, by introducing 1.5-2% vol. of oxygen into the CPE (Fig. 4).

The less σ, the smaller liquid droplets are and there appears the likelihood of transition to fogging and spray transfer of metal. In this way the additive of oxygen up to 5% reduces the surface tension of the steel during welding in an inert gas.

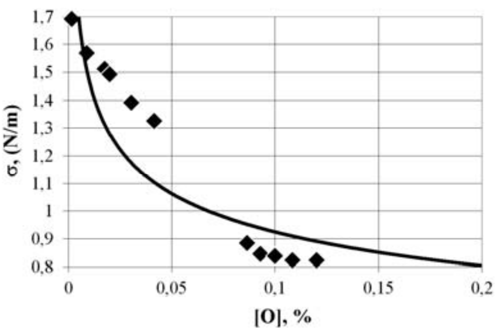

Fig. 4. Influence of density of oxygen on a surface tension of alloys Fe-O at 1600 °C

When welding on the reverse polarity the anode spot is stable at the end of the liquid drop and the current is increased, the density remains constant, and the spot size increases. Therefore, drop overheating and boiling occur at lower currents than on normal polarity when the cathode spot moves randomly. With current density increasing, for example, for $j>20$ A/mm^2 electrocapillarity effect can be observed, accompanied by σ decrease contributing to spray transfer of metal.

Therefore, the change in the composition of CPE can produce favorable conditions for the transfer of electrode metal into the weld pool, as CPE composition change varies its redox potential, the drops temperature and the arc electrode metal, the drops surface tension.

Another feature is that the CPE should securely protect the weld pool and the arc of the air space in the overhead position. This is achieved using CPE with gas phase He.

The condition of air marginalization when welding in the overhead position:

$$\frac{m_{CPE}}{V_{CPE}} \le \rho_{air}, \tag{6}$$

where: m_{CPE} – CPE weight (kg), V_{CPE} – CPE volume (m^3), ρ_{air} – density of air (ρ_{air}=1.206 kg/m^3).

After the transformation (Eq. 6), we obtain the expression for determining the multiplicity of CPE, at which the density is less than that of the CPE air:

$$k \ge \frac{(\rho_l - \rho_{He})}{(\rho_{air} - \rho_{He})}, \tag{7}$$

where: ρ_l – the density of the CPE liquid phase (ρ_l=1.05·10^3 kg/m^3).

After substitution of the numerical values in the expression (Eq. 7), we obtain the value of the multiplicity of the CPE $k \ge 1021.724$.

Possible applications of the CPE in the welding industry.

The use of welding to the CPE in the manufacture of structures, was primarily determined by local companies. These companies were "Lugansk Teplovoz", "Snezhnyansk khimmash" and Stakhanov Wagon Works.

At "Lugansk Teplovoz" there were developed new types of diesel-trains and passenger cars with a high level of comfort that do not require major repairs body for 35 – 40 years (Fig. 5).

The total weight of the construction of cars new type is much less due to the use of steel 10H13G18DU with special strength properties. Roof and side walls are responsible nodes. According to the specifications the roof is made of steel VSt3ps GOST11474-76 and the side wall – of stainless steel 10H13G18DU. The thickness of the metal roof and the side wall is 1.5 mm and in certain areas of the side wall it is 1 mm. The frame is made of steel bent channel VSt3ps with the thickness of 2.5 mm. The roof is made of three spans, the length of two of them is 9570±3 mm, and – 5470±3 mm. The transition from the roof to the side wall is performed with the inclined and bent sheets 1003.55.00.148 and 1003.55.00.149 of VSt3ps steel. Sheet width is 320±1 mm, the width

Fig. 5. A general view of the diesel-trains and diesel train car

of the flat part is 304±1 mm, bending angle is about 160°. In the upper part (the connection of roof with list) there is performed a continuous seam due to the requirements of tightness. At the bottom there is a connection of dissimilar materials. The great length of the upper seam (total length of about 25 m) and the presence of dissimilar materials in conjunction with the side wall sheets causes the significant deformation sheets 1003.55.00.148 and 1003.55.00.149, which leads to deterioration of appearance and aerodynamics of the car.

Traditional methods for reducing strain during welding and post weld treatment (dressing, rolling, stretching, heat treatment, etc.) are not applicable because of the large dimensions of the product [10, 11].

It was suggested to use cooling with CPE on the entire length of the seam (Fig. 6).

As a result, the welding area $2b_{\text{п}}$ was 30% narrowed in a one-sided feeding CPE and 45 – 50 % for double-sided CPE feed, which leads to lower overall deformations to an acceptable level. Forced cooling has a positive effect on the structure of welds, as evidenced by joint research with "Lugansk Teplovoz" [11, 12, 13]. This method allows to reduce the stress and strain of the base metal by heat during welding [17].

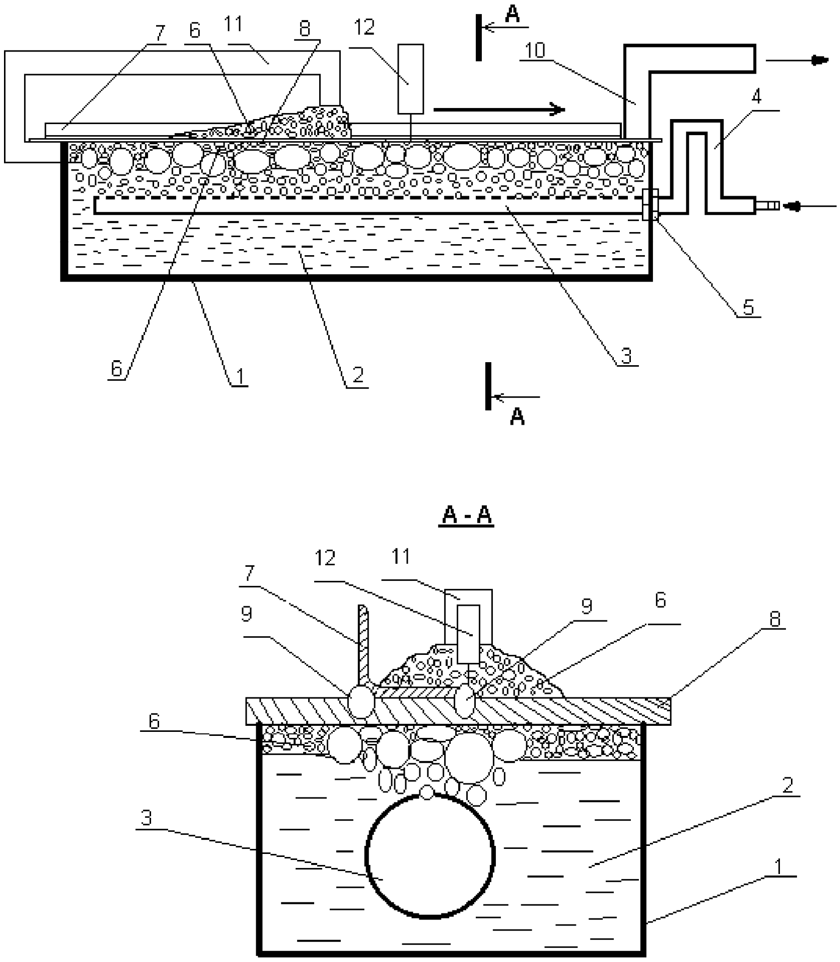

Fig. 6. The scheme of the welding with forced cooling CPE: 1 – a tank with a liquid phase CPE, 2 – CPE liquid phase, 3 – dispersant, 4 – cutter to prevent splashing in the system for supplying an activating gas, 5 – nut to prevent spillage of liquid, 6 – CPE layer to drain parasitic heat from the welding zone, 7 – welded element, 8 –sheet metal, 9 – welds, 10 – sleeve for removing excess CPE, generating steam and gas, 11 – sleeve for supplying CPE welded to the outer side elements, 12 – the welding head

It minimizes the structural transformations in the weld metal and heat affected zone, the tendency to intergranular corrosion after exposure to welding thermal-cycle, reduces the probability of the formation of metastable structures, phases and the associated instability of the product dimensional characteristics in time.

As a result of CPE, dimensions of the core and compressive stresses in the sheet decreased, and they did not reach critical values, therefore, buckling did not occur, and the deformation of the sheet does not exceed the permissible levels.

Comparing the results of measurement of car sidewalls deformations assembled and welded with cooling and without cooling, it is seen that in cars that are welded with cooling, deformation is less than 60 – 70 %.

The use of CPE welding in the manufacture of diesel train car wall reduced labor costs by reducing the welding deformation and at the same time improve the quality of products.

Stakhanov Wagon Works "SWW" launched production of containers under the base of KAMAZ, GAZ trucks, etc. (Fig. 7).

The container is a thin-list structure made of VSt3ps steel in the form of duct with walls with thickness of 3 mm, reinforced ribs in the form of channel sections of steel bent VSt3 thickness of 3 – 4 mm. Semi-automatic welding CO_2 is used as a welding method. Welding mode: I_w=120 – 150 A, U_a=20 – 22 V, V_w=16 – 18 m/h. The current technology of the container provides for forced water cooling from the back side of the seam weld ribs in the form of U-sections (Fig. 8).

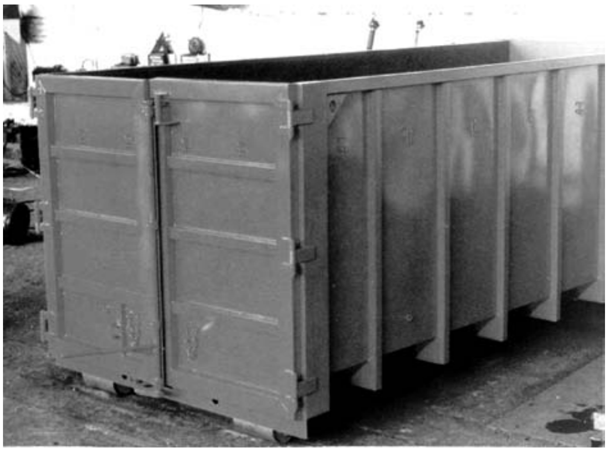

Fig. 7. Exterior view of the SWW

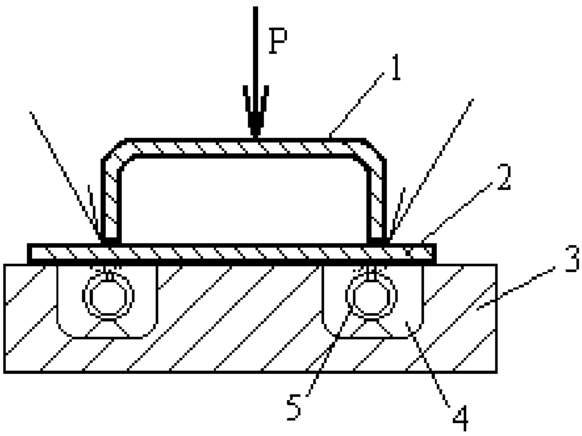

Fig. 8. Cooling scheme design for welding stiffeners: 1 – U-section, 2 – list 3 – bedding, 4 – trench, 5 – a tube with holes

The cooling results in a narrowing of the core sheet by 70 % and overall shrinkage force is reduced by 45% [17]. In addition , application center of the force is shifted up and to the various sections of the eccentricity of the application shrink force towards the center of gravity is reduced by an average of 20%. The total reduction in residual strain was 56 % compared to welding in the free state. As a result, the longitudinal deflection of 2.9 mm.

However, the allowable strain – 1 mm to 1 m long. To achieve acceptable values of deformations on the technology there are used clamping devices (i.e. anchorage welding)

We have proposed to use a combined method of forced heat (water and by CPE) to reduce the welding deformation. Container design has a number of nodes that are difficult to weld with forced cooling using the current technology, e.g. Fig. 9. The main challenge is to hold the refrigerant – water on the surface of a complex profile of welded parts.

Combined method of heat removal is illustrated in Fig. 8 and is the following. The nodes are welded water-cooled from the back side of the seam according to the existing technology, additional heat is performed by CPE, which is served at the welding torch from the front and in profile of the welded stiffeners in the form of a sill.

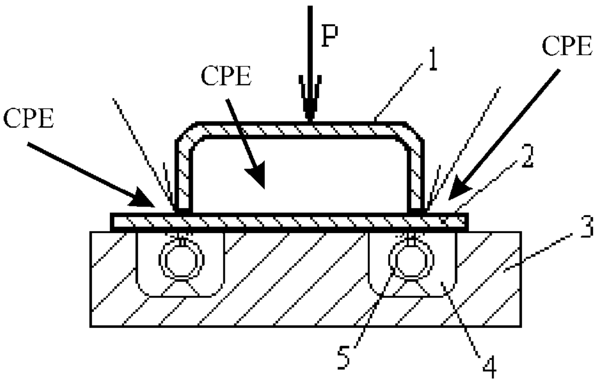

Fig. 9. Welding scheme of combined heatsink

Container units welding shown in Fig. 10 is implemented on standard welding modes recommended by the technology of the container manufacturing, with the forced cooling of CPE units. And also there are welded full-scale test sample data nodes in a CPE. Refrigerant in the form of CPE was fed to the front side of welded seams, as well as in the cavity formed by profile rolling in the form of U-sections and beams of rectangular, square cross-section forms, by introducing into the cavity of sleeve feed CPE.

Combined heat sink reduces the residual strain by an average of 60%, which makes it possible to abandon the cumbersome pressers and do not exceed the allowable values of deformations.

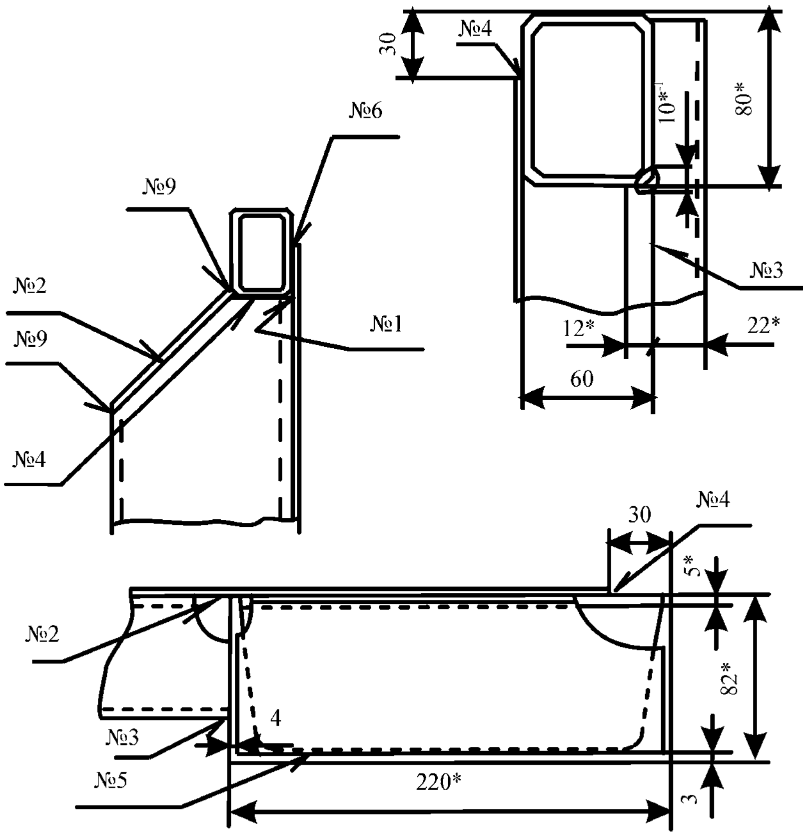

Fig. 10. Welded container sidewall nodes, welded with forced cooling by CPE

The results of this work provide a basis to conclude that the possibility of the use of welding the container in CPE, as well as the possibility of welding important structures of low carbon structural steel in CPE.

Chemical equipment nomenclature manufactured by the "Snezhnyansk khimmash" includes evaporators, liquid traps, adsorbers, filters, heat exchangers, rectificational column at manufacture of which there are used welding shells up to 6000 mm and a diameter of 1600 mm, the thickness of the metal 3, 4, 6, mm.

Relation of core sizes is different (Table 1), e.g., at a thickness of 3 mm, diameter 273 mm, length 1500 mm (Fig. 11).

Shells are made with one or more welds. All types of welding lead to a residual deformation, for example, bend along the longitudinal axis amounts to 6±2 mm, there is formed a non-circular cross-section, which requires calibration and post weld dressing.

For the manufacture of shells there were used VSt3sp, 09G2C, 15HM.

Table 1. The spectrum scheme for construction of welded oil separator, manufactured by "Snezhnyansk khimmash"

Обозначение	D_y	L	B	H	∅		Volume (m^3)	Mass (kg)
					А	Б		
МОВ-125	500	1900	650	670	125		0.320	240
МОВ-150	600	2260	750	770	150		0.550	370
МОВ-200	700	2360	650	870	200		0.630	480
50 МА	257	1230	440	420	50		0.05	102
80 МА	307	1350	480	490	80		0.078	140
100 МА	408	1800	550	550	100		0.180	227

For the manufacture of chemical equipment it is necessary to ensure receipt of designs with minimal deviations from the standard sizes. To minimize the welding strains on the shells there was proposed to use forced heat against welding torch. In the automatic welding shells 3 mm – 4 mm I_W=120 – 150 A, U_a=20 – 22 V, V_W=16 – 18 m/h, feeding CPE about 20 – 40 mm against the welding torch according to the proposed in [6], the deformation of deflection is reduced by an average of 40 – 50 %, thus reducing the cost and time for post-weld operations.

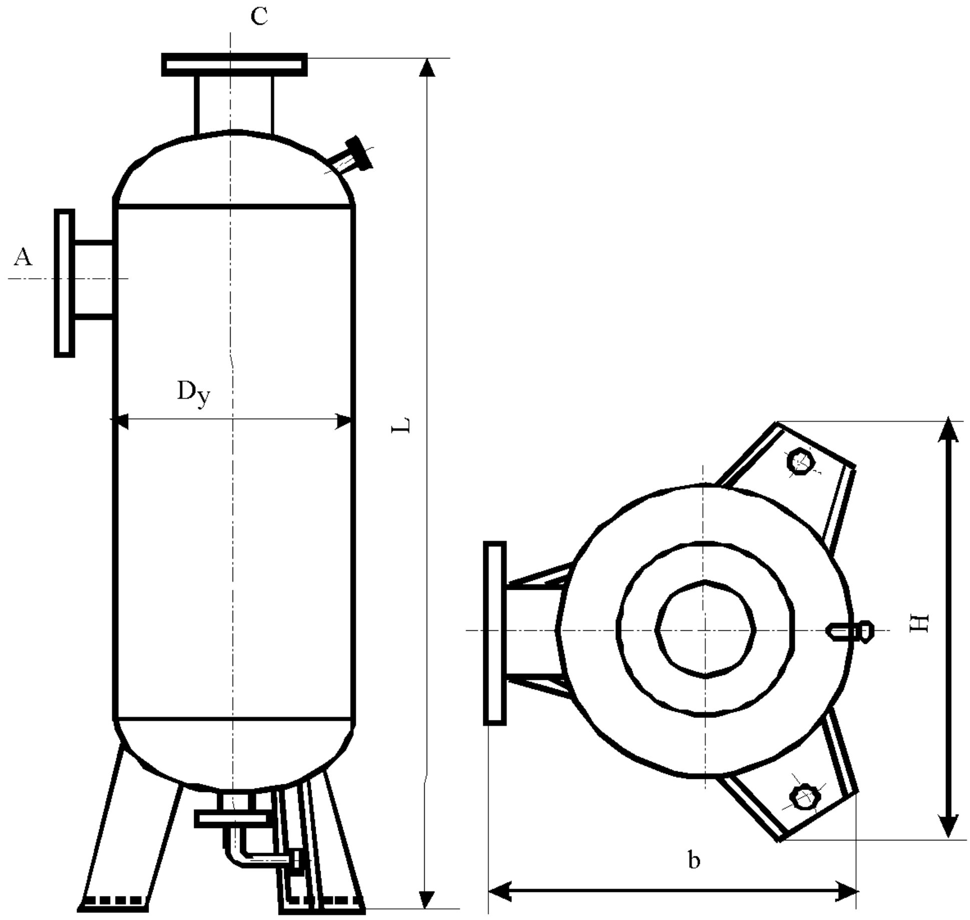

Fig. 11. Scheme for construction of welded oil separator, manufactured by "Snezhnyansk khimmash"

CONCLUSIONS

1. For ceiling seams welding as filler gas CPE there is a need to use helium (He) or a gas mixture which is lighter than air.

2. Changing the composition of the CPE can adjust the surface tension of the molten metal.

3. The use of the CPE, as the refrigerant is possible for constructions (welded nods) of any shape and contour, in any position.

4. Welding with the CPE fits easily into the process and helps to reduce residual stresses and strains.

5. When using a combined method of heat (water on the back side of the seam, and CPE – from the front) there is minimal residual deformation, which eliminates the anchorage of welded structures.

6. CPE may be used as a protective environment for products of structural steels.

7. There were suggested the methods and apparatus for welding of thin sheet hull structures with minimal residual strains.

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ОСОБЕННОСТИ СВАРКИ С ПРИМЕНЕНИЕМ КОМПЛЕКСНОЙ ЗАЩИТНОЙ СРЕДЫ

Олег Друзь, Светлана Житная.

Аннотация. В данной статье изложены результаты экспериментальных исследований по сварке в комплексной защитной среде (КЗС). Приведены особенности сварки в нижнем и потолочном пространственном положении. Описаны возможности применения сварки с применением КЗС на предприятиях региона.

Ключевые слова: сварка, комплексная защитная среда, сварочные деформации.