Technological Peculiarities of Welding of Thin-walled Shells for Multilayer Silphon Equalizer

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The experience in manufacturing of multilayer silphon equalizers (SE) out of BT1-00 alloy and results of the check test for determination of service life characteristics which was carried out in accordance with the approved programs, has shown that the earlier used methods of thin-walled shells welding, that is: semimash, pressure contact and automatic argon-arc welding used at assembling of both butt and lap joints had considerable shortcomings because the reliability of hydraulic forming of multilayer siphons of new design and the requirements for durability were not ensured.

Pressure contact welding resulted in formation on the surface of multilayer siphons of visible prints looking like linear zigzags because this kind of welding is carried out at "lap" assembling. As a result there were formed additional stress concentration which affected adversely at cyclic loads.

Transition to automatic argon-arc welding has allowed for some increase of the level of structures durability, however, in the process of hydraulic forming of siphons there was found an inadmissible large percentage of fractures along a weld seam, on the boundary of fusion zone and thermal effect. This disadvantage look place in spite of the fact that BT1-00 alloy has good plasticity and the level of harmful impurities meet the "Greid-1" requirements.

It was determined that numerous facts of fracture at forming of siphons out of shells with 0.3mm thickness were caused by formation of structurally mechanical and chemical heterogeneity in a welded joint. Unfavourable character of hydrogen distribution in a welded joint was determined experimentally, fig. 1.

On the basis of the carried out studies which included the checking of mechanical properties under different types of loadings: uniaxial loading for tension and two-axial loading by hydrostatic stretching (the test diagram and evulation is given in fig.2) and on the basis of metallographic test it has become possible to explain the mechanism of fractures appearance which consists in the following: at hydraulic forming of siphons a welded joint got under the influence of two-axial stretching in zone of plastic deformation, and grain boundaries in fusion zones and thermal effect serve as the barriers for dislocations movement and restrain plastic deformation of a grain. As a result in zone of restrain there are formed "peaks" of stresses with cause formation of linear cracks.

In order to increase the working capacity of welded joints performed by automatic argon-arc welding in the process of hydraulic forming which is followed by considerable deformation up to 25-30% it was chosen as optimum a method of rolling or heat treatment and machining, which was carried put using the equipment for semimash contract welding, for example, МШИ -15-14 plant.

The difference of this procedure from the contact welding consists in the purpose: i.e. a reliable metallic bond is not required. Therefore there should be chosen the conditions less strict as compared with the contact welding conditions. The interval between current pulses is usually set as a minimum when selecting the welding conditions, current of heating and compression force is equal to (50-60% of these parameters which are used at contact welding. In order to carry out a stable process of heat treatment and machining it is necessary to use contact welding rolls made of copper alloys with brinell hardness (200 units and it is also necessary to smooth the surface of weld seam performed by automatic argon-arc welding.

This procedure is carried out by cold cogging of a weld seam, a value of swageing being preset. It was experimentally determined that the condition of heat treatment and machining of a zone of welded joints of thin-walled shells made of BT1-00 alloy stimulate the superplastic effect (SPE).

The process parameters were determined by calculations:

\[ \varepsilon = 4,1 \times 10^{-2} - 6,2 \times 10^{-2}C-1 \]

\[ \varepsilon_1 = 3,3 - 6,7 \% \]

\[ T = 920-950^\circ C \] where

\[ \varepsilon \] deformation rate

\[ \varepsilon_1 \] deformation degree

\[ T \] - temperature in the centre of plastic deformation

These conditions can be reached by heating of metal in a zone of roll-metal contact when AC (50hr) of a density about 120 A/mm² supplied.
Fig. 1 Temperature distribution in thermal effect zone at automatic argon arc welding (1), hydrogen distribution in heat effect zone (2)
Diagram of test for hydrostatic stretching

Base metal
Fracture along weld seam zone
Fracture across seam zone

Maximum deformations zone at stretching

\[ h_{w_i} \geq 0.8_{B.M.} \]

Fig. 2
Studies of weld seam metal microstructure and thermal effect zone have shown that there is a complete transformation of the initial coarse-grained structure with a grain size about 300\textmu\textit{mkm} into a globular fine-grained structure with a grain size about 7 \textmu\textit{mkm}, what provides for the total structural full-strength of a welded joint, besides, at heat treatment and machining hydrogen concentration "peaks" in a welded joint zone are completely eliminated (Fig.3). As a result of heat treatment and machining of weld joints it is reached a stable full-strength of welded joints and base metal under conditions of silphons forming.

Bench trial which were carried out in the Central Design Bureau “Compensator” within the frames of the interbranch test program (ITP) and included the following tests:
- for strength, density an stability
- for cyclic strength
- for vibration
- for confirmation of cyclic strength margin
- for strength under dynamic loads.

These rests have shown that the industrial introduction of the development technology of thin-walled shells welded joints performing out of BT1-00 alloy at enterprises of the industry concerned with production of silphons allows for 2-2.5 times increase of service life of titanium silphon equalizers and for practical elimination of rejects at production of multilayer silphons.

In fig 4 there is a view of multilayer silphon.

Fig. 3 Microstructure of thermal effect zone
1) after welding
2) after thermal and machining
Fig. 4