Device for electropulse press-fitting of pipes into a tube sheet of shell-and-tube heat exchanger

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Abstract. The article presents theoretical information about pulse methods of press-fitting pipes into the tube sheet of the shell-and-tube heat exchanger. Analysis was made of the existing designs of devices for electropulse press-fitting pipes in the tube sheet, the identified weaknesses of these devices. The design of the device for press-fitting into the tube sheet by the electropulse method is developed, which is devoid of the disadvantages of the designs considered in this article. A distinctive design decision is the use of a reusable shank with a support flange. The shank is made of metal and is presented in the form of bellows compensator. The second distinctive decision is the use of a gap sealer between the device body and the pipe, which has no chemical affinity with the device body. The paper describes in detail the principle of operation of the proposed device. Also we developed a drawing of the proposed design of the device for press-fitting pipes into the tube sheet of the shell-and-tube heat exchanger.

1. Introduction

Heat exchangers are widespread in all industries where heat and mass transfer processes occur in one way or another. Particular attention is paid to heat exchange equipment in the chemical, petrochemical, and oil refining industries, where the share of heat exchange equipment among all equipment is maximum. Only in the refining industry, the share of heat exchanging equipment is about 40% of the total metal of the plant [1]. It should be noted that there is no tendency to reduce the share of heat exchangers, hence, heat exchangers today are very relevant.

High requirements for the performance of heat exchangers, their high cost and time-consuming repairs require the search for effective methods and technologies that ensure an increase in their service life while remaining operational properties. [2]

The reliability of shell-and-tube heat exchangers is determined by the level of the stress-strain state of their compounds [3, 4]. The total voltage in the compounds depends on a large number of factors, such as: stresses occurring from the manufacturing techniques of the device; contact stresses that occur during the installation; operational stresses associated with the parameters of coolants (primarily pressure and temperature); dynamic stresses caused by high velocities of heat carriers, etc [5 - 8].

However, the basis of their designs is a set of pipes, hermetically connected to a tube plate. Accordingly, the reliability, service life and performance of these devices is determined by the quality of the connection of pipes with tube sheets [9]. During the exploitation, the heat exchanger pipes are clogged with sediments (sometimes up to the complete overlap of the bore holes) and as a result the sealing is broken in such places as the pipes themselves and the places of their pressing in the tube plates. The repair work regulations considers the operations of installing plugs, removing defective pipes and replacing them with new ones if the number of defective pipes is more than 15% of the total number. Repeated operations of pressing and unpressing pipes from tube grids, usually, lead to the appearance of defects on the surface of the holes of the tube plates, which cannot be removed during the subsequent preparation of the holes. Currently, such heat exchangers are replaced by new ones, while companies have to bear large economic and time costs. Therefore, today the search for methods and technologies that extend the service life of heat exchangers [10] is relevant.

Usually, in the production conditions, traditional mechanical methods are used to press in pipes, mainly with a rolling tool, but in the case of large defects (caverns along the entire opening, changing its shape and size), this method is fundamentally unable to extend the operational life of heat exchangers. [11]

The purpose of this work is to increase the reliability of the connection “pipe-tube grid”.

2. Perspectivity of impulse methods of press-fitting tubes into a tube sheet

The problems of press-fitting tubes in tube sheets of heat exchangers were studied together with the issues of sheet metal forming. Roller flaring found a widespread application for mounting pipes in tube sheets, patented in 1953, which is still used in production, despite the difficult working conditions [12].

When processing pipes made of high-strength materials (for example, titanium) with an inner diameter of less than 10 mm over a length of more than 60 mm, the resistance to flaring dropped sharply. The performance remained low, about 5-30 compounds per hour. The axial deformation, which occurred in the process of rolling, destroyed the weld of the preliminary curing, which prevented the possibility of obtaining a combined compound according to GOST RU 55601-2013. Thinning of pipes, high residual stresses, stress concentrators in the places of transition of a flared and non-flared pipe, accompanied by low corrosion resistance, quickly disrupted heat exchangers, leading to accidents. Modernization of roller expansion with the introduction of the drive and the torque control device did not deprive it of its main fundamental flaws.

Impulse methods of press-fitting tubes into tube sheets allow the use of special electric pulse installations (EPI), which are used to transfer electrical energy from a pulse current generator to a working cartridge. EPI control is carried out remotely from the control panel.

In turn, when the impulse is pressed in with the help of explosives, the possibility of simultaneously fixed pipes is significantly increased, at the same time it is possible to press about 400 pipes and more [13]. But the risk of cracking is significantly increased due to the large shock stress that occurs during the pressing process. Therefore, it is preferable to use the method of electric explosion.

The use of electric explosion (EE) allows automatic control of energy parameters, control of the process of energy release, the creation of an optimized process and mechanized high-performance equipment [12].

Compounds obtained by EE with pressing are more reliable in conditions of long-term operation. It was tested using accelerated thermoshydrocyclic tests that simulate the loads acting on compounds that are adequate in terms of the nature of the operational. Heat exchangers were tested on a special stand.

The statistical estimate of the mean time to failure of compounds obtained by EE with pressing exceeds the corresponding indicator of compounds obtained by mechanical flaring, sometimes more than 25 times. This is confirmed by the experience of operating heat exchangers at the respective facilities [12].

It is also worth noting that the industrial sites and workshops for pulsed processing of high-strength metals based on explosive technology created in the former USSR made it possible to gain about 1 billion rubles at the defense enterprises of the Soviet country [14].

The first results of the research and their analysis confirmed the viability of working on the impulse of press-fitting, and predetermined the relevance of further development of work in this direction [12].

3. Review of existing devices' designs for electropulse press-fitting the pipes into a tube sheet

The known design of the cartridge for electropulse press-fitting the pipe presented on Figure 1 [15].

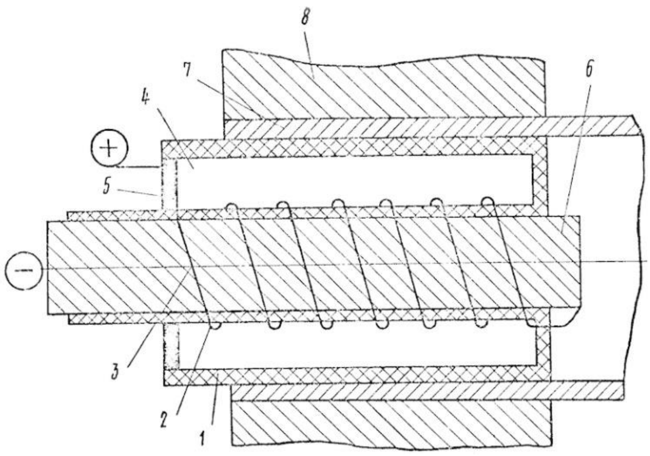

Figure 1. Cartridge design for electropulse pipe press-fitting:
1 – body, 2 – inner body, 3 – exploding conductor, 4 – filler, 5 – sealer, 6 - cylindrical rod,
7 – heat exchange tube, 8 – tube sheet.

The current pulse from the current pulse generator enters the conductor, where upon the latter explodes. Explosion creates a pressure pulse, which is transmitted through the filler to the walls of the body and then to the pipe walls. The metal rod, being a current lead, fills the volume of the cartridge, thereby increasing the pressure in the cavity filled with filler. After press-fitting the heat exchange tube, the rod is removed and used again.

The disadvantages of this design (Figure 1) [15] are the lack of efficiency (loss of pulse pressure) and the unstable gap between the cartridge and the pipe during the press-fitting. The loss of pulse pressure is caused by the presence of excessive gap between the cartridge and the pipe as well as the possible breakdown of this gap. In turn, the unstable gap does not allow evenly distributing the magnitude of the pulse pressure on the inner wall of the pipe. Together, these shortcomings affect the effectiveness of the cartridge used and also quality and stability of the press-fitting process.

Also, there is the design of an electro-explosive cartridge for press-fitting pipe presented on Figure 2 [16], in which the sleeve of the cartridge body, having a small diameter in the initial state, is easily inserted into the end of the pipe. After that the electrode approaches the current lead of the shank and moving, reduces the volume of the transmitting fluid in the cavity of the shank. It leads to an increase in the sleeve prior to its junction to the inner surface of the heat exchange tube. Then, using an electrode, a current pulse is passed through the conductive element, which leads to the release of portions of energy in the pressure transmitter acting on the pipe wall, which is press-fitting it into the tube sheet.

The disadvantages of the construction described above (Figure 2) [16] are: firstly, lack of reliability and low efficiency of the cartridge, due to the fact that the shank is not protected from possible longitudinal and transverse deformations, both at the time of axial movement under the influence of the electrode, and at the time of press-fitting the pipe into the tube sheet. It affects the gap between the body of the cartridge and the pipe by uneven filling of the filler at the time of axial displacement of the shank.

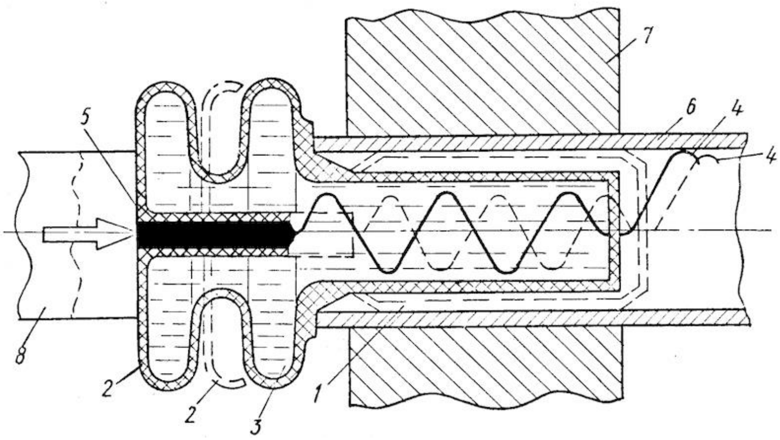

Figure 2. Cartridge design for electropulse pipe press-fitting:
1 – sleeve, 2 –shank, 3 – pressure transmitter, 4 – explosive element, 5 – current lead, 6 – heat exchange tube, 7 – tube sheet, 8 – electrode.

Secondly, the sealer is absent, which does not allow to completely isolate the fit location of the shank with the pipe, thereby creating the possibility of a breakdown in this place. As a result, there are losses of impulse pressure on the walls of the pressing-in pipe, hence the stability and quality of the press fitting is deteriorated. Thirdly, it is available for only a single use, due to the shank being made of easily deformable material, which makes it impossible to reuse it.

4. The proposed device for electropulse press-fitting of pipes into the tube sheet of a shell-and-tube heat exchanger

The device for press-fitting pipes into a tube sheet (Figure 3) comprises a body (hollow cylinder) of dielectric material 1 with a filler (pressure transmitter) 2 and a shank-bellows 3, which is in threaded connection with the body 1.

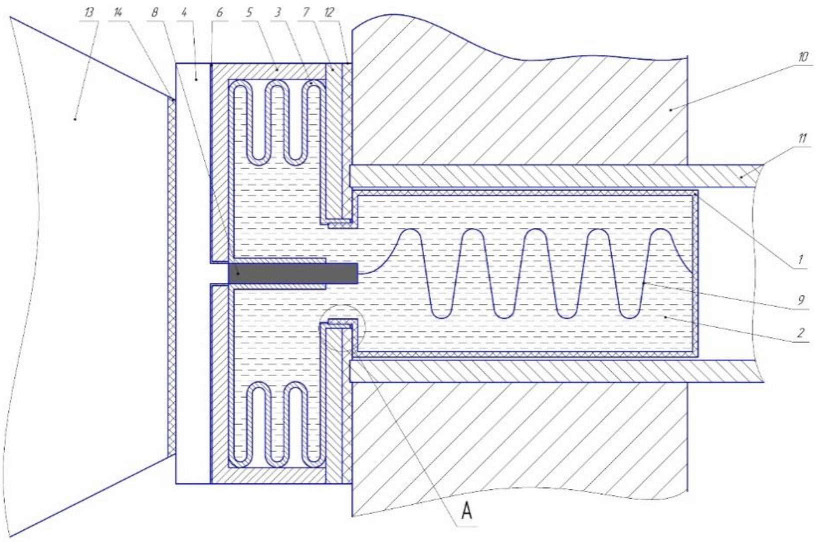

Figure 3. The proposed device for pulse press-fitting pipes into a tube board of a shell-and-tube heat exchanger: 1 – body, 2 – pressure transmitter, 3 – shank-bellows, 4 – electrode, 5 – cup, 6 – insulator, 7 – support flange, 8 – current conductor, 9 – exploding conductor, 10 – tube sheet, 11 – heat-exchange tube, 12 – sealer, 13 – anvil, 14 – insulator.

The end of shank-bellows is provided with a cup 5 and faces the electrode 4, and has insulator 6on the inner and end surfaces. A support flange 7 is installed on the other end of the shank-bellows 2. In the body 1 there is a current conductor 8 and an exploding conductor 9. The conductor 9 has a spiral shape and is installed in contact with the electrode 4 through the current conductor 8. At the near end, to the tube sheet 10 and the pipe 11, the shank-bellows 3 has a sealer 12, made in the form of a ring of a material that does not have a chemical affinity with the material of the support flange 7.

The operation of the device for press-fitting the pipe into the tube sheet is described below (Figure 3). First, the body 1 is connected to the shank-bellows 3 using a threaded connection. Then the cartridge is filled with pressure transmitter 2 and is inserted into the end of the heat exchange pipe 11, which is located in the tube sheet 10.Next, the electrode 4 moves towards the end of the shank-bellows 3 which is equipped with a cup 5 and an insulator 6. The insulator 6 serves for the directed supply of pulsed current to the conductor 8. The cup 5 and the support flange 7 serve to protect the bellows from lateral and longitudinal deformations at the moment of press-fitting pipe 11 into the tube sheet 10, and at the moment of movement of the electrode 4, providing directional transverse compression, thereby reducing the working volume of the filler 2, which makes the gap between the body 1 and pipe 11 minimal.

Then the electrode 4 is supported by the anvil 13, which prevents the movement of the shank-bellows 3 to its original position. In place of the pairing of the anvil 13 and electrode 4 there is an insulator 14. Next, the source of pulsed current through the electrode 4 supplies a current pulse to the cartridge through a conductor 8 to the exploding spiral element 9, which subsequently transmits the blast energy to the wall of the cartridge 1, and then to the pipe wall 11 through pressure transmitter 2.When the cartridge 1 explodes, the end losses do not occur due to the sealer 12, which makes it possible to compensate for the roughness of the end face of the pipe 11 and the tube sheet 10 with the support flange 7, thereby ensuring uniform fit of the support flange 7 with the tube sheet 10 and obtaining reliable pulse pressure insulation at the moment of press-fitting. Shank-bellows 3 also partially performs the function of a reflector, due to fixing in the compressed position of the shank 3 by anvil 13, it compensates for the excess pulse pressure that falls into the cavity of the shank-bellows 3, and reflects them to the end of the pipe 11.

5. Discussion

The wide possibilities of control and adjustment of parameters during the impulse pressing of pipes, including EPI as well, make it possible to predict the resulting compound much better. The use of an electropulse press-fitting method reduces the contact stresses at the joints of the pipe with the tube sheet [10, 17].

The analysis of the device designs [15, 16] for electropulse press-fitting of pipes showed that a significant drawback in the design is the lack of proper sealing of the end surface at the location of the device’s body with the heat exchanging pipe, thereby creating end pressure pulse losses during press-fitting and affecting stability and quality the resulting compound.

The proposed device is designed to substantially reduce the deficiencies of the device structures considered in this paper [15, 16], due to the use of a sealer that prevents breakdown in the gap between the device body and the pipe, and use of a special shank in the design, having a design of the bellows-compensator.

The use of the intended device allows ensuring stable process of press-fitting, the result is a better and more reliable connection, which operational life will be significantly longer than with roller rolling of pipes. This confirms the promising development and application of pulsed methods of fitting pipes into tube sheets.

The article presents theoretical information about the impulse methods of press-fitting pipes into the tube sheet. Weak points are revealed in the considered designs of devices for electropulse press-fitting of pipes. The proposed design of the device is aimed at correcting the design flaws of the analogues. The proposed design is shown in the drawing and described in detail in this article.

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