Design of replaceable nozzles for connecting pipelines in electron beam welding

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Abstract. The article is devoted to the use of electron beam welding for connecting pipelines in the oil and gas industry. The analysis of the proposed approach and equipment for creating permanent pipe-flange connections is carried out. The advantages and disadvantages of the proposed approach are considered. During the work, the welded seam was calculated. A set of interchangeable attachments for the turntable has also been developed. Thus, the purpose of this work is to improve the quality of welded joints of oil and gas equipment through the use of electron-beam welding technology and design of replaceable nozzles for a turntable for an electron-beam welding unit.

1. Introduction

Nowadays, the question of improving the quality and reliability of oil and gas equipment in the oil and gas industry has become very popular. The decrease in quality and reliability can be influenced by such factors as corrosion, fragility, human factor, aggressive environmental conditions, etc. [1-3]. Practically in the oil and gas industry, we use metal products and objects, structures and structures that help us extract natural resources from the bowels of the Earth. For complete and safe extraction, we must first of all take care of the quality of the material used in the work, as well as its reliability and durability [4-6].

Oil and gas equipment include many different elements and their connections required for operation. For example: oil pipes for pumping and distilling oil, wells, drills, etc. All these metal elements are prone to redox processes, i.e. to spontaneous destruction of metal. Especially often, these processes are observed at the junctions of two or more metal elements. Soldering or welding is often used to connect the elements. Welding methods, involving the melting of the base material of the welded products to a state of fluidity, change for the worse the properties of the product, deformation and internal stresses occur [7-9]. Welding is the process of obtaining permanent joints by establishing interatomic bonds between the parts to be welded during their local or general heating, plastic deformation, or the joint action of both. Various sources of energy are used in welding: electric arc, electric current, gas flame, laser radiation, electron beam, friction, ultrasound. The development of technologies makes it possible at present to carry out welding not only in industrial enterprises, but in the field and installation conditions (in the steppe, in the field, in the open sea, etc.), under water and even in space.
At the first stage, it is necessary to bring the surfaces of the materials being welded closer to the distance of the action of the forces of interatomic interaction. Ordinary metals at room temperature do not bond under compression even with significant forces. The combination of materials is hindered by their hardness; when they approach, actual contact occurs only at a few points, no matter how carefully they are processed. The bonding process is strongly influenced by surface contamination - oxides, fatty films, etc., as well as layers of absorbed impurity atoms. For these reasons, it is impossible to fulfill the condition of good contact under normal conditions. Therefore, the formation of physical contact between the joined edges over the entire surface is achieved either due to melting of the material, or as a result of plastic deformations resulting from the applied pressure [10-12].

At the second stage, electronic interaction is carried out between the atoms of the surfaces to be joined. As a result, the interface between the parts disappears and either atomic metallic bonds are formed (metals are welded), or covalent or ionic bonds (when welding dielectrics or semiconductors). Based on the physical nature of the process of forming a welded joint, three classes of welding are distinguished: fusion welding, pressure welding and thermomechanical welding.

Fusion welding includes types of fusion welding without applied pressure. The main sources of heat in fusion welding are the arc, gas flame, radial energy sources and Joule heat. In this case, the melts of the metals to be joined are combined into a common weld pool, and upon cooling, the melt crystallizes into a cast weld [13-16]. Thermomechanical welding uses heat energy and pressure. The joining of the parts to be joined into a monolithic whole is carried out due to the application of mechanical loads, and the heating of the blanks ensures the required plasticity of the material.

Pressure welding refers to operations carried out with the application of mechanical energy in the form of pressure. As a result, the metal deforms and begins to flow like a liquid. The metal moves along the interface, taking the contaminated layer with it. Thus, fresh layers of material come into direct contact, which enter into chemical interaction.

2. Materials and methods

In the production of metal structures, the most reliable method of connecting individual parts to each other is welding. In this case, the strength of the adhesion is provided by the intermolecular interaction that occurs under the influence of high temperature. In order for the joints (tracks, seams) of the finished product to turn out to be of high quality, before starting work, the calculations of the weld must be correctly performed. Accurate calculations are needed to select basic and consumables, to understand how reliable and monolithic the structure will be.

Let's calculate the weld seam of a flange joint in a circle with an inner diameter equal to 219 mm and a thickness of 28 mm (figure 1). The calculation of the welded seam is performed according to SNiP II-23-81 p.11.1.

![Figure 1. Flange weld.](image)

Allowable stresses for butt welded joints of machine-building structures, Pa. Calculated by the formula (1):
\[ [\sigma]_p = 0.9[\sigma], \]  

(1)

where \([\sigma]\) – permissible stress of the base metal, Pa.

For steel 08KH18N10T \([\sigma] = 490\) MPa. Allowable stress for the welded seam according to the formula (1), Pa:

\[ [\sigma]_p = 0.9 \cdot 490 \cdot 10^6 = 441 \cdot 10^6. \]

The permissible tensile load for a welded joint is calculated by the formula (2), N:

\[ F = [\sigma]_p \cdot l \cdot \Delta, \]

(2)

where \(l = 2\pi R\) – weld seam length, m; \(\Delta\) – weld leg, m.

The tensile load of the weld is calculated (3):

\[ F = S \cdot P_{oper}. \]

(3)

where \(S\) – cross-sectional area m\(^2\); \(P_{oper}\) – operating pressure.

Let’s calculate the weld seam of a flange joint in a circle with an inner diameter equal to 159 mm and a thickness of 22 mm (figure 2). The calculation of the welded seam is performed according to SNiP II-23-81 p.11.1.

Figure 2. Flange weld.

Let’s calculate the weld seam of a flange joint in a circle with an inner diameter of 133 mm and a thickness of 18 mm (figure 3). The calculation of the welded seam is performed according to SNiP II-23-81 p.11.1.
Let's calculate the weld seam of a flange joint in a circle with an inner diameter equal to 108 mm and a thickness of 16 mm (figure 4). The calculation of the welded seam is performed according to SNiP II-23-81 p.11.1.

Let's calculate the weld seam of a flange joint in a circle with an inner diameter of 89 mm and a thickness of 13 mm (figure 5). The calculation of the welded seam is performed according to SNiP II-23-81 p.11.1.
A summary table of the strength calculation of welded joints of flanges is presented in table 1.

### Table 1. Strength calculation summary table.

| Flange inner diameter, m | Flange thickness, m | Weld seam length, m | Permissible load, N | Breaking load, N | Condition $F \leq F_1$ |
|--------------------------|--------------------|---------------------|-------------------|-----------------|----------------------|
| 0.219                    | 0.028              | 0.68766             | 1.13$\cdot10^6$   | 75.2$\cdot10^3$  | performed            |
| 0.139                    | 0.022              | 0.49926             | 0.82$\cdot10^6$   | 39.68$\cdot10^3$ | performed            |
| 0.133                    | 0.018              | 0.41762             | 0.6865$\cdot10^6$ | 27.76$\cdot10^3$ | performed            |
| 0.108                    | 0.016              | 0.33912             | 0.5575$\cdot10^6$ | 18.312$\cdot10^3$| performed            |
| 0.089                    | 0.013              | 0.27964             | 0.4594$\cdot10^6$ | 3.9$\cdot10^3$   | performed            |

Thus, the condition $F \leq F_1$ is fulfilled for all sizes of welded joints of flanges with a pipe.

### 3. Result and discussion

As a result of the work, a rotary table with an attachment was designed. Figure 6 shows a schematic diagram of a rotary table.
Figure 6. Rotary table with attachment: 1. Rotary table motor; 2. Welded rotary table; 3. Nozzle; 4. Cartridge rotation motor; 5. Bearing; 6. Cartridge; 7. Drive pulley; 8. Belt.

Figure 7 shows a schematic diagram of attachments for fixing flanges with nipples.
4. Conclusion
A technical proposal was formulated, which consists in improving the design of equipment for electron beam welding, an installation for electron beam welding of flange joints was designed, which makes it possible to improve the quality of the weld and increase the productivity of equipment, the issue of economic efficiency of electron beam welding was considered and the calculation of the welded seam.

The essence of the TETA installation with the designed nozzles is to improve the quality of welded joints between the flange and the pipe.

The nozzle consists of two round plates with a diameter of 700 mm (upper and lower), between which there is an ACD-B1 asynchronous displacement motor, the upper plate is held by means of welded legs, which are inserted into special grooves in the lower plate. On the top plate there are so-called cartridges, into which the pipe is inserted and held in an upright position, a flange is put on the pipe and fixed in the desired position. The chucks in the top plate are mounted on bearings and have one pulley each through which the drive belt runs. A drive pulley is brought up from the displacement motor, which is on the same level with the rest of the pulleys and drives the cartridges, substituting the junction of the flange and pipe under the beam for welding.

Acknowledgments
The study was funded by a subsidy from the Ministry of Science and Higher Education of the Russian Federation for the creation of a youth laboratory "Laboratory of Biofuel Compositions" as part of a government assignment.

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