Device for connecting elements of main oil and gas pipelines using electron beam welding

E G Kravcova¹, Yu F Kaizer¹, V S Tynchenko¹,², S Ch Mongush³, S N Katargin¹ and P Yu Vaitekunaite²

¹ Siberian Federal University, 79, Svobodny pr., Krasnoyarsk, 660041, Russian Federation
² Reshetnev Siberian State University of Science and Technology, 31, Krasnoyarsky Rabochy Av., Krasnoyarsk, 660037, Russian Federation
³ Tuva State University, 36, st. Lenin, Kyzyl, 667000, Russian Federation

E-mail: rina_986@mail.ru

Abstract. The article deals with the problem of connecting pipelines in the oil and gas industry. To improve the quality of welds on the oil pipeline, the article proposes an alternative method of welding and venting the beam into the atmosphere. This method includes a mobile installation for electron beam welding, in which, in manual mode, it is possible to adjust the seam speed, penetration depth, change the trajectory of the weld and the position of the installation relative to the pipe axis. Guns with a plasma cathode, which allow welding products in the atmosphere, are considered. The power of the generators is also calculated, and the generators are selected corresponding to the put forward requirements. In the course of the work, the authors are designing an electron beam welding unit, which in the future is planned to be developed as a mobile one. The mobile installation includes: a generator directing the belt to the pipe, a horizontal displacement motor, a welding positioner, an electron gun with a plasma cathode.

1. Introduction

There was a time when the output of the beam into the atmosphere was impossible, and welding was carried out only in vacuum chambers, where there was no atmosphere. But today there are already cannons for ejecting an electron beam into the atmosphere [1-3]. Based on the results that were described in the article and the experiments carried out, electron guns with beam parameters that were not previously achieved were created [4-6]. These guns can be used both in traditional vacuum electron-beam technologies and in conditions under which increased requirements for the geometric dimensions of the electron beam become decisive, for example, in gas-dynamic systems for extracting beams into the atmosphere or into a high-pressure gas [7-9]. The ability of the created guns to operate at pressures that are an order of magnitude higher than the permissible pressures of hot-cathode guns, their insensitivity to possible breakthroughs in the atmosphere, together with improved characteristics, make it possible to significantly simplify equipment, increase its reliability, and open up new possibilities for using electron beams.

As a result of the analysis of scientific literature, it is possible to pick up the electron guns already available in our time, which are represented by the company “ELION” LLC. At the moment, there are
three types of guns that differ from each other by the consumed energy: Gun with plasma cathode 30kV, 40kV, 60kV. The gun is shown in figure 1.

The gun includes cathode assembly, housing, high-voltage cable, focusing and deflecting systems, gas flow regulator (as agreed with the customer).

The gun can provide stable parameters of the electron beam for a long time, under conditions of “technical” vacuum and frequent depressurization of the working chamber of the installation, including emergency ones. The gun does not lose performance when exposed to metal vapors and gas emissions from the welding zone and has a long service life. It is possible to place the gun both inside and outside the vacuum chamber.

The principle of operation of a gun with a plasma cathode is based on the emission of electrons from the plasma under the action of a high-voltage electric field. A Penning-type discharge (low-voltage reflective discharge with a hollow cathode) is used to generate emitting plasma.

2. Materials and methods
Electrons with a sufficiently high energy can penetrate the processed material to a certain depth [10, 11]. The maximum depth, passing which the electron loses its energy, depends on the accelerating voltage and density of the processed material and can be expressed by the relationship (1), micron:

\[ \delta = 2.35 \cdot 10^{-12} \frac{U^2}{\rho}, \]  

where \( \delta \) - penetration depth, [cm]; \( U \) - accelerating voltage, [V]; \( \rho \) - density of the processed material, [g/cm\(^3\)].

At the maximum stress of the gun for steel with a density of 7.8 g/cm\(^3\) at a stress \( U = 120 \) kV, \( \rho \approx 0.0043 \) mm.

\[ \delta = 2.35 \cdot 10^{-12} \frac{120^2}{7.8} = 4.34. \]

Consequently, the energy of the electron beam is converted into thermal energy inside the thin surface layer.

To improve the quality of the welded joint, I suggest using a gun with a plasma cathode 120 kV, because with less energy consumption, we will not be able to boil a sufficiently wide metal in butted
joints, and with increased energy consumption, we can get a rigidly bonded joint without deformation and melting a large amount of metal in the seam zone.

A good, powerful welding generator is also needed to get the mobile machine up and running. Particular attention must be paid to such an important characteristic as the rated power of an autonomous generator. For diesel generators, it should be 50% higher than the power consumed by the inverter.

Based on the characteristics of the gun, we select a generator with a power reserve of 20%. After looking through the catalogs of welding machines, the following welding generators are suitable.

When choosing a generator, pay attention to the fact that we need a mobile three-phase generator with a capacity of 150 kW, because in the process of welding oil pipes, we will move the installation from place to place, therefore, based on economic indicators and mobile indicators, the option “g - Generator TSS ED-150-T400-2RKM19” is suitable for us (figure 2).

![Generator TSS ED-150-T400-2RKM19](image)

**Figure 2. Generator TSS ED-150-T400-2RKM19.**

Diesel station technical characteristics:

- Number of phases - 1 phase 3 phases.
- Power (kW) - 150.
- Maximum power (kW) - 165.
- Net weight (kg) - 3410.
- Fuel type - Diesel.
- Length (mm) - 4500.
- Width (mm) - 1950.
- Height (mm) - 2590.
- Startup type - Automatic.
- The volume of the fuel tank (L) - 400.
- Fuel consumption (L/h) - 29.60.
- Engine type (with or without crankcase) - Four-stroke.
- Frequency (Hz) - 50.
- Engine model - TDK 170 6LT.
- Price – 1.329,990 rubles.

When designing a manipulator, we must pay attention to the external dimensions and welding range, as well as mass, so that the manipulator does not push or deform the pipe. The manipulator must rotate around the pipe axis. According to this principle, the manipulator will move in each direction without changing its trajectory at a given speed. The movement engine with the control panel will help us to
regulate the speed. With the help of this motor, we can adjust the position of the gun in each range and move the manipulator along the axis at a constant speed, without interrupting the welding mode. When analyzing welding projects, “VOSKHOD” orbital welding complex was chosen, which will be an analogue to the proposed welding method. But we will not consider the entire complex, but only its moving part, namely: the guide belt to the pipe, the motors for horizontal and vertical movement, the release lever.

3. Result and discussion

Elements such as oscillation unit, spool holder, welding head motor, wire feeder will no longer be required.

Having designed a manipulator and an electron-beam gun, we will get our own electron-beam welding (EBW) installation, which is shown in figure 3.

![Figure 3. Installation of EBW. 1 - pipe; 2 - guiding belt; 3,4 - displacement motors; 5 - release lever; 6 - rollers of movement; 7 - electron beam gun; 8 - seam; 9 - holders.](image)

With the help of the guide belt, the possibility of pipe deformation and punching is reduced, the belt dimensions are regulated within the range of $\Phi 114-1400mm$. It also excludes the possibility of beveling the weld when moving the manipulator along the belt vertically. The release levers help to secure the manipulator to the belt, which squeeze the belt on both sides with rollers. Drive rollers allow the unit to be moved around the pipe axis. The rollers must be able to support 120 kg. With the help of a horizontal motor, the gun can move in each range, and with the help of the holders, we can adjust the height from the pipe, or the seam, to the gun.

4. Conclusion

The article develops an alternative method for joining pipes in the oil and gas industry, namely, electron beam welding without using a vacuum. In order to improve the quality of welds on the oil pipeline. This method includes an electron beam welding installation, in which, in manual mode, it is possible to adjust
the seam speed, penetration depth, change the trajectory of the weld and the position of the installation relative to the pipe axis. The authors considered and selected a gun with a plasma cathode, which allows welding products in the atmosphere. And also, the power of the generator was calculated, and the generator was selected corresponding to the requirements. In the course of the work, the authors have designed an electron-beam welding unit, which in the future is planned to be developed as a mobile one.

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