Design of an induction brazing installation for connecting oil and gas equipment

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Abstract. The article is devoted to the design of a circuit diagram of an induction heating device. The work carried out a literature review in the area under consideration. The technology of manufacturing a union is considered, which consists of manufacturing a plug, a branch pipe and a flange. Conducted research and application of induction brazing and various fields. Various elements of the equipment used in the design process are considered. A schematic flow diagram of the induction brazing unit has been developed. As a result of the work, the design of the installation for induction soldering was developed and auxiliary materials (flux, solder) were selected.

1. Introduction

The induction brazing process allows for simple and reliable regulation and does not require preheating of the parts to be brazed. Typically, this technology is used to solder copper wire with a diameter of about 0.1–15 mm. Thin wire or conductive paths of printed circuit boards are only conditionally amenable to induction soldering. For sensitive electronic components that can be damaged by induction currents, induction soldering is not suitable. Low voltage electrical assemblies and electrical components such as plug connectors are usually produced by selective induction soldering. This technology is used, for example, by manufacturers of electrical appliances, as well as automotive components. [1-3].

The use of induction brazing is currently widespread and is generally used in the following industries:

- Mass production of parts of simple configuration.
- Mechanical engineering, automotive industry.
- Metalworking industry.
- Electrical industry.
- Manufacturing of medical equipment, etc.
The use of induction soldering ensures the connection of any conductive materials - any metals and alloys, as well as ceramics with metal spraying. In addition, induction brazing allows [4-6]:

- Heat only a specific part of the part.
- Control the soldering process using measuring instruments.
- Reduce human participation in the process.

Due to this, induction brazing is widely used in such industries as aviation, space [7-9].

Induction heating units (IHU) are widely used in various technological processes in machine-building and other industries. They are divided into two main types: through heating and surface heating installations.

Plants for soldering, quenching and through heating, depending on the purpose, are powered from alternating current networks at a frequency from 50 Hz to hundreds of kHz. Power supply of high and high frequency installations is made from thyristor or machine converters. The installations belong to category II power consumers in terms of the degree of power supply reliability.

Compared to other types of heating (in flame furnaces and resistor heating furnaces), induction heating has a low waste of metal and less waste due to the ingress of scale into the workpiece. Through-heating induction units are used to heat workpieces for subsequent plastic deformation: forging, stamping, pressing, rolling, etc. [10-12]. Depending on the geometrical parameters of the heated parts and their material, the power supplies of induction installations are made at a frequency of 50–10000 Hz. For through-heating installations, the operating frequency is selected so that heat is released in a layer of sufficient thickness over the section of the part in the absence of a large temperature gradient between the surface and a layer of a certain thickness. In this case, there will be less overheating of the surface of the workpiece and higher efficiency of the installation.

According to the operating mode, through heating installations are divided into batch and continuous installations.

In batch plants, only one piece or part of it is heated. When heating blanks made of magnetic material, a change in power consumption occurs: first, it increases, and then, upon reaching the Curie point, it decreases to 60–70% of the initial one. When heating blanks made of non-ferrous metals, the power at the end of heating increases slightly due to an increase in the specific electrical resistance [13-15].

2. Materials and methods
To connect the pipeline, valves, various containers and other parts of gas, liquid and conversion systems, a small connector is used, which is called a fitting.

The fittings for vessels and apparatuses are a cylindrical part, one of the sides of which is machined for connection with another part. Fittings are manufactured in accordance with ATK 24.218.06-90 and can be manufactured in five types, each of which can be manufactured in several versions.

Fittings are used in oil refining, petrochemical, chemical, gas and other related industries.

Depending on the technical purpose, the fittings can be made in various designs.

Consider the technology of manufacturing a fitting for a pressure vessel. In this case, the choke is an assembly unit that consists of the following parts:

- Plug.
- Branch pipe.
- Flange.

For the long-term functioning of the fitting, it is necessary that the working parts do not wear out for a long time; for this, the manufacturing technology of the parts must be observed. Table 1 shows the technology for manufacturing a plug for a waste heat boiler nozzle.
Table 1. Stub manufacturing technology.

| Operation name | Equipment | Note |
|----------------|-----------|------|
| Operation 005 Cutting | Plasma machine with CNC Start 2A 15-30 (Plasma-Gas) with two cutters | Sheet dimensions 2500x1000x18 (according to GOST 19903-74), material: steel 09G2S |
| 1 Installation and fastening of the workpiece (sheet); | | |
| 2 Cut a circle $\Phi$ 335 mm. | | |
| Operation 010 Stripping | Pneumatic chisel or grinding wheels | |
| 1 Trim away burrs and other cutting marks. | | |
| Operation 015 Turning | CNC lathe TS-35 | |
| 1 Install and fix the workpiece; | | |
| 2 Sharpen the end surface | | |
| 3 Sharpen the end surface, ensure $\Phi$ 259 mm, $t = 4$ mm. | | |
The required precision in the manufacture of parts depends on the correct design of the mechanisms of machines and devices. Therefore, the correct choice of parameters for the manufacture and processing modes of parts ensures the maximum durability of their work during the period of operation.

3. Result and discussion

As part of the research, it is necessary to develop a schematic flow diagram of an induction soldering installation, which will allow displaying its main parts and their interaction with each other.

We know that the inductor is an element of the induction brazing installation that directly heats the area to be brazed. Since energy does not come from anywhere and does not disappear anywhere without a trace, a power source is needed. Can be used as a power source:

- Power frequency network 50 Hz.
- Machine frequency converters, from which a current is obtained with a frequency of 500 to 8000 Hz.
- Lamp generators - current sources with a frequency from 70 kHz to several megahertz.

The most widespread in industry are installations powered by machine frequency converters.

The heating mode is controlled by an electric machine or a magnetic amplifier. The switching on and off of heating by a contactor is used when several heating devices are supplied in parallel from one generator.

With an individual power supply of the heating device, the heating can be switched on and off both by a contactor and by switching on and off the generator excitation.

A set of measuring instruments with current and voltage transformers is used to monitor the operating mode of the device.

A high-frequency autotransformer is used to regulate the voltage supplied to the inductor and, therefore, the power transmitted to the heated workpieces. An autotransformer is installed in the case of centralized power supply. With individual power supply of a single heating device, the voltage supplied
to the inductor is changed by regulating the excitation current of the generator. The dimensions and shape of the inductor are determined by the dimensions and shape of the workpiece, as well as the required performance of the device.

A photopyrometer with an amplifier is used as a sensor for the automatic heating control system.

The heated workpieces are fed into and out of the inductor for further processing using a special mechanism.

Thus, considering all of the above, we will develop a schematic flow diagram of an installation for induction soldering, the diagram of which is shown in figure 1.

![Figure 1. Schematic diagram of an induction heating device: 1 - high frequency transistor current generator; 2 - electric machine amplifier that controls the heating mode; 3 - contactor for switching on and off heating; 4 - cabinet with measuring instruments and equipment for controlling the operation of the electric machine amplifier 2; 5 - high-frequency transformer for voltage regulation on the inductor; 6 - inductor; 7 - capacitor bank.](image)

One of the tasks of this work is the development of the design of the installation that allows soldering of the nozzle flanges by the induction heating method. Having performed preliminary calculations of the inductors, I concluded that this soldering method can be carried out for this area. Also, based on the calculated power consumption of the inductors and the frequency, I chose the existing characteristics of the equipment that are capable of implementing this method in this area.

The developed installation consists of an alternating current source, a generator, an industrial computer, a soldering station control unit, an inductor, a control panel, a pyrometer, an ammeter. The design of the induction brazing unit will be based on existing units manufactured by Petra. The general view of the facility being developed is shown in figure 2.
Figure 2. Installation for induction soldering. 1 - AC source; 2 - industrial computer; 3 - contactless pyrometer; 4 - table; 5 - transistor induction high frequency current generator; 6 - regulation of the hydraulic valve; 7 - inductor.

To carry out the process of induction soldering of flanges of fittings, the following steps must be taken:

- Prepare the workplace for work.
- Lay the union down with the flange.
- Place the solder, treat the surface to be brazed with flux.
- Ensure the position of the inductor with respect to air gaps, excluding its interaction with the part to be soldered.
- Switch on the equipment, presetting the heating speed and temperature.

The soldering temperature and the time for maintaining this temperature are provided by a photopyrometer, which is part of the installation control system.

4. Conclusion
As a result of this work, the design of the general view of the technological system of the installation for the induction brazing of the flanges of the nozzles of the vessels operating under pressure for the set of inductors for the induction brazing of the flanges of the nozzles for the nominal diameter $D_{y1} = 40$ mm was performed; $D_{y2} = 50$ mm; $D_{y3} = 80$ mm. The implementation of the literature review allowed us to understand the device and the principle of operation of installations for induction soldering, and also made it possible to study the existing methods of joining parts to be soldered by the method of induction heating.

References
[1] Murygin A V, Tynchenko V S, Kurashkin S O, Bocharova O A, Seregin Y N and Bocharov A N 2021 Automated installation for pipelines brazing in protective environments using induction heating IOP Conference Series: Materials Science and Engineering 1047(1) 012110
[2] Kojima M 2016 Fossil fuel subsidy and pricing policies: recent developing country experience.
[3] Zhao W W, Yan J C, Yang W and Yang S Q 2008 Capillary filling process during ultrasonically brazing of aluminium matrix composites Science and Technology of Welding and Joining 13(1) 66-9

[4] Murygin A V, Tynchenko V S, Laptenok V D, Emilova O A and Bocharov A N 2017 Complex of automated equipment and technologies for waveguides soldering using induction heating IOP Conference Series: Materials Science and Engineering 173(1) 012023

[5] Eustathopoulos N, Hodaj F and Kozlova O 2013 The wetting process in brazing Advances in brazing 3-30

[6] Tynchenko V, Kurashkin S, Tynchenko V, Bukhtoyarov V, Kukartsev V, Sergienko R, Kukartsev V and Bashmur K 2021 Mathematical Modeling of Induction Heating of Waveguide Path Assemblies during Induction Soldering Metals 11(5) 697

[7] Khaja A S, Kaestle C, Reinhardt A and Franke J 2013 Optimized thin-film diffusion soldering for power-electronics production In: Proceedings of the 36th International Spring Seminar on Electronics Technology 11-6

[8] Tynchenko V S, Milov A V, Kurashkin S O, Petrenko V E, Tynchenko Y A and Rogova D V 2021 Mathematical model of the waveguide pipe heating in the process of induction brazing IOP Conference Series: Materials Science and Engineering 1047(1) 012112

[9] Yao Z, Xue S and Zhang J 2020 Comparative study on the activity of GaF3 and Ga2O3 nanoparticle-doped CsF-AlF3 flux for brazing 6061 Al/Q235 steel joints Crystals 10(6) 498

[10] Milov A V, Tynchenko V S, Kurashkin S O, Petrenko V E, Rogova D V and Tynchenko Y A 2021 The induction heating process modelling of the waveguide paths’ flanges IOP Conference Series: Materials Science and Engineering 1047(1) 012027

[11] Hou L, Moelans N, Derakhshandeh J, De Wolf I and Beyne E 2019 Study of the effect of Sn grain boundaries on IMC morphology in solid state inter-diffusion soldering Scientific reports 9(1) 1-14

[12] Yokota K, Minami T, Michitsuji H, Fujio T and Yamada S 2004 Occupational dermatitis from soldering flux Industrial health 42(3) 383-4

[13] Tynchenko V S, Murygin A V, Petrenko V E, Emilova O A and Bocharov A N 2017 Optimizing the control process parameters for the induction soldering of aluminium alloy waveguide paths1 IOP Conference Series: Materials Science and Engineering 255(1) 012017

[14] Qu L, Zhao N, Zhao H J, Huang M L and Ma H T 2014 In situ study of the real-time growth behavior of Cu6Sn5 at the Sn/Cu interface during the soldering reaction Scripta Materialia 72(2) 43-6

[15] Hawksworth D K 2013 Fluxless brazing of aluminium In: Advances in brazing 566-85