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Automation of experimental research of waveguide paths induction soldering

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Abstract. The article presents an automated system of experimental studies of the waveguide paths induction soldering process. The system is a part of additional software for a complex of automated control of the technological process of induction soldering of thin-walled waveguide paths from aluminum alloys, expanding its capabilities. The structure of the software product, the general appearance of the controls and the potential application possibilities are presented. The utility of the developed application by approbation in a series of field experiments was considered and justified. The application of the experimental research system makes it possible to improve the process under consideration, providing the possibility of fine-tuning the control regulators, as well as keeping the statistics of the soldering process in a convenient form for analysis.

1. Introduction

Induction heating technology is widely used in industry [1, 2, 3], both for the formation of permanent joints of product elements and for supporting technological operations intended to improve the physical properties of products materials [4, 5, 6]. The method of induction heating for the formation of solder joints has proved itself well in the production of antenna-feeder pathways. The applying of this method allows one to improve radio technical characteristics of pathways, to reduce weight by 40%, to reduce production costs 2-2.5 times in comparison with welded analogs [7].
The use of such high-tech method for the formation of integral joints is complicated by the presence of a number of external factors, the most complex of which are [8]:

- A low degree of recurrence of the non-automated soldering process.
- The proximity of the base material and solder melting temperatures (660 ˚C and 560 ˚C respectively).
- Features of pyrometric sensors for measuring the temperatures of the assembly elements.
- Uneven distribution of electromagnetic fields during induction heating between the elements of the assembly.
- The influence of the human factor.

Figure 1 shows waveguide samples with pronounced defects, such as: local overheating, disruption of the base material integrity, no seepage, no formation of a solder joint.

Figure 1. Waveguides with defects.

Defects arise due to the output of the technological process for permissible deviations - the so-called necessary conditions for the formation of a quality solder joint.

Thus, it can be concluded that the solution of the current problems of the technological process under consideration is feasible in various directions, representing separate tasks. These directions could be designated as follows:

- Development of complex profile inductors providing induction currents in the closest possible proximity to the joint to be soldered [9].
- Application of the effective intelligent control methods.
- Optimization of the process in the framework of the used algorithms.
- Improving the quality of temperature feedback.
- Development of multifunctional software.
- Carrying out experiments aimed at studying the technical process as a whole, which will allow one to reveal the necessary data for all the points listed above.

This article is devoted to the solution of the indicated problems in several areas: the development of multifunctional software and carrying out experimental studies of the process.

2. Designing a software system for conducting experimental research

Figure 2 shows the functional diagram of an automated control complex of the induction soldering technological process of thin-walled waveguide paths.

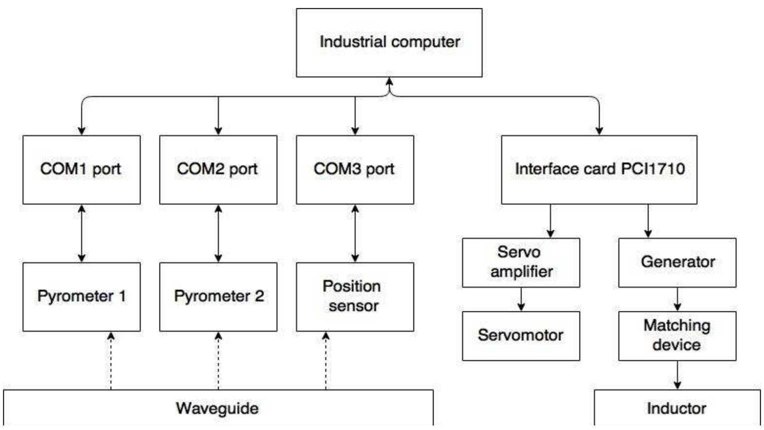

Figure 2. A functional diagram of a complex of automated equipment for two-loop control of the induction soldering process.

To control the temperature of the waveguide in the heating zone, two pyrometers are used. Temperature data come from pyrometers to the industrial computer via its internal channel through the COM ports. The position of the waveguide relative to the inductor is controlled by an optical position sensor. The monitoring data are sent to the industrial computer via a COM port.

The induction heating of the waveguide is controlled by two channels: the generator power control channel and the waveguide position control channel. The control channel of the position of the waveguide consists of a servo amplifier and a drive connected to the waveguide. According to the position of the waveguide in the inductor (the gap between them), an appropriate control action is formed by the industrial computer.

The power control channel consists of a generator and a matching device. The signal controlling the generator's power is passed from the industrial computer through the interface card to the generator. The matching device ensures the transfer of energy from the generator to the inductor, performing induction heating of the waveguide.

The variety of the nomenclature of the standard sizes of waveguide pipes necessitates the periodic re-adjustment of the technological process:

- Separation of each standard size and then making the technological process map.
- Adjustment of parameters of already existing technological process maps due to a significant tolerance for the thickness of waveguide tubes causing a non-uniformity in mass of about 10%. In addition, this adjustment may be required when soldering different curvilinear sections of the waveguide assembly.
- Change in the coefficients of the pyrometers emissivity in the case of impossibility of monitoring the temperatures near the soldering area due to design features of the standard size. In some cases, the adjustment of such coefficients allows achieving an improvement in the quality of the process.

Thus, the developed automated experimental research system was required to provide the following main functions:

- The ability to keep statistics of the induction soldering process and to display its state during execution in a visual form, suitable for perception and analysis.
- Reduction of the time spent on adjusting the process to a certain standard size, in particular, the ability to configure the process directly during its execution.
- Configuration and diagnostics of the equipment used.

Figure 3 shows a block diagram of the software for an automated complex of experimental studies, which includes two autonomous subsystems having their own structure defined by nested functional blocks: a subsystem of experimental research support and a subsystem of technological process control.

The subsystem of technological process control includes the following modules:

1) The control module, which is the main window of the program that ensures the interrelationship and stable operation of the remaining blocks of the system, transfers the necessary parameters and data to other modules.

2) The module for the collection and display of information about the technological process allows one to display the current status of the process, as well as transmits information from the sensors to the main module. It monitors the boundary movements of the servo drive, calculates and transmits data from the pyrometric and position sensors to the main program module, displays heating schedules for the user.

3) The controller module is a software implementation of the logical controllers used in the system. The control loop for maintaining the heating temperature set is an integral regulator, which uses logical conditions for the purpose of better regulation. The regulator of the position control of the assembly relative to the inductor window is a complex logical function, the elements of which are

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proportional, differential and proportional-differential regulators with proper coefficients. The control type is selected based on the current process status data. [10]

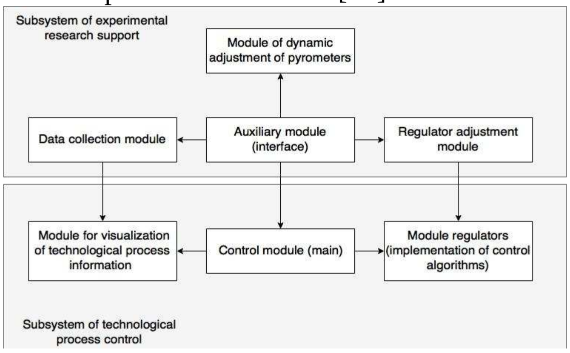

Figure 3. A block diagram of the experimental research of the automated system software.

3. Software for experimental research of waveguide paths induction soldering

The main program window, shown in figure 4, is a form with controls, a menu and a heating graph of the waveguide assembly elements.

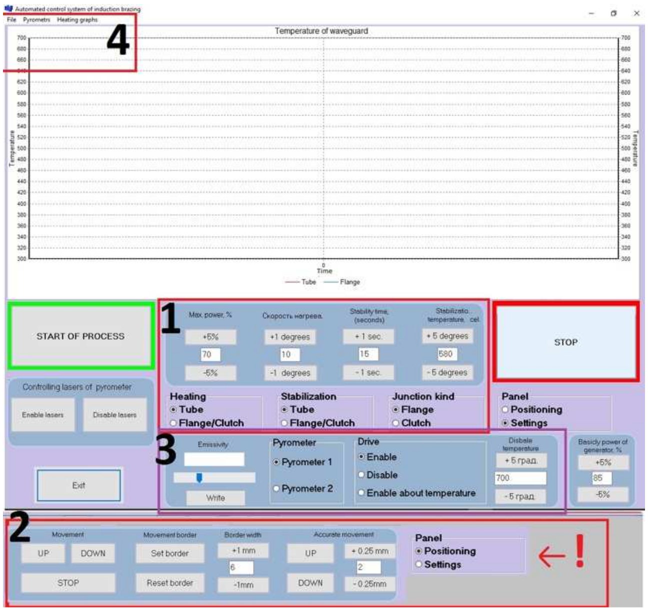

Figure 4. The main window of the software for experimental research of waveguide paths induction soldering.

The controls on the form are grouped according to the nature of their functional:

- Group 1 - adjustment of process parameters. The operator of the system can set all the necessary parameters of the technological process: control settings, selection of the soldered connection type and selection of the assembly element, which will be used for regulation purposes.
- Group 2 - servo control elements, which are used by the operator to position the waveguide relative to the inductor window, and also to determine the boundary position of the movement in order to form an allowable positioning area, which provides the ability to specify the power of the generator, which will be initiated at the start of the technological process.
- Group 3 - additional settings that allow the operator to reset the emissivity of pyrometers during the soldering process, as well as to determine the activity of the drive.

- Group 4 - main menu, which allows the operator to save the process charts, open the process status display form and the pyrometer configuration form.
- Service elements, including buttons: "START PROCESS ", "STOP", "Exit", "Enable / Disable lasers".

4. Results and discussion

For the purpose of experimental investigation of the proposed system efficiency, samples of waveguide tubes of various standard sizes with the type of soldered joint "pipe-flange" were used. Initially, the soldering process was started with arbitrary parameters, and in the subsequent series of experiments, successive corrections were made based on the analysis of the data obtained as a result of the next start-up. Figures 5 - 8 show the results of the soldering process obtained as a result of approbation of the system with various settings of the control regulators, as well as the initial process parameters for the standard size of 58x25 mm.

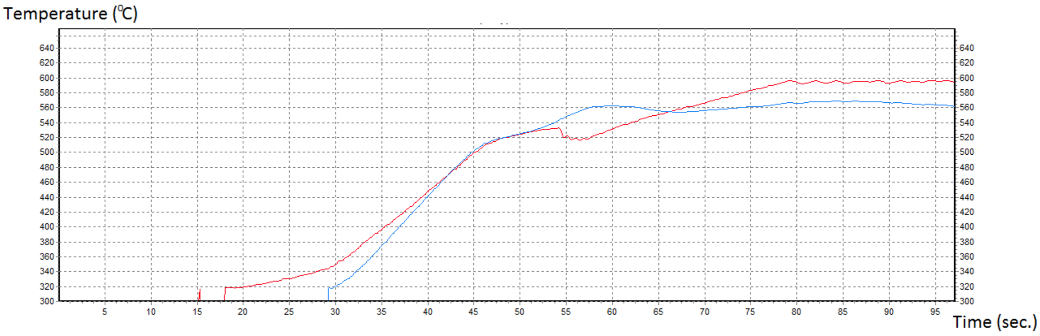

Figure 5. A temperature chart of soldered elements during the experimental stage. The red graph is the temperature of the pipe; the blue graph is the temperature of the flange.

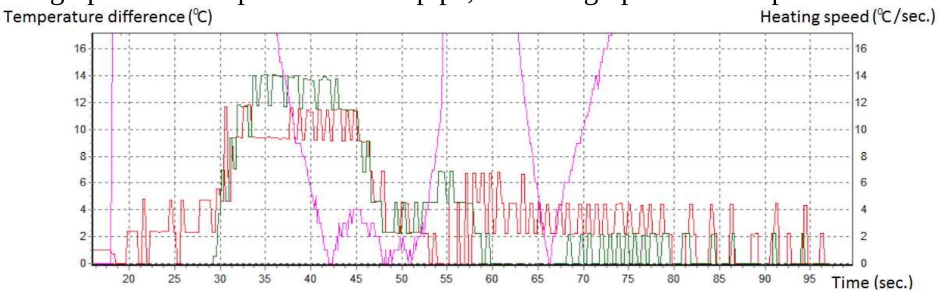

Figure 6. Dynamics of technological parameters of the waveguide assembly heating. The red graph is the heating rate of the flange; the green graph is the heating rate of the pipe; the magenta graph is the temperature difference between the assemble elements.

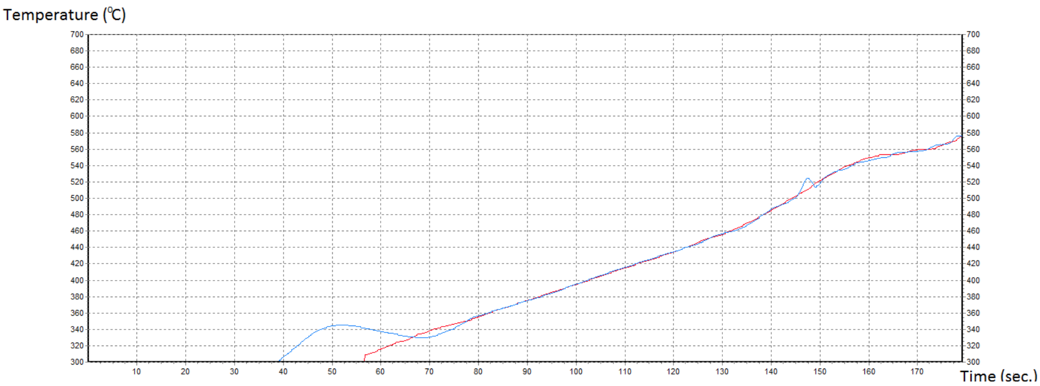

Figure 7. A temperature chart of soldered elements after parameters adjustment. The red graph is the temperature of the pipe; the blue graph is the temperature of the flange.

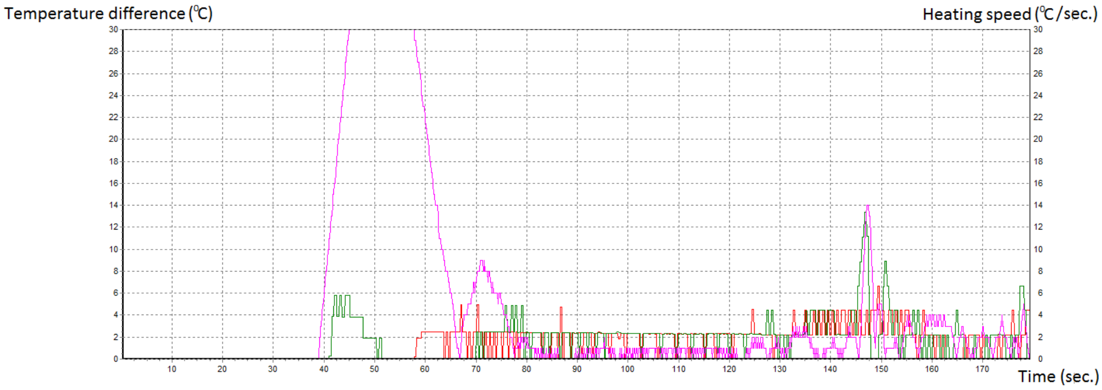

Figure 8. Dynamics of technological parameters of the waveguide assembly heating. The red graph is the heating rate of the flange; the green graph is the heating rate of the pipe; the magenta graph is the temperature difference between the assemble elements.

When analyzing the process graphs in figures 5 and 6, the process parameter settings and the gain factors of the regulators were corrected. So, at the time intervals of the soldering process from 55 to 65 seconds and from 70 to 90 seconds, the heating mode mismatch is noticeable, which is due to uneven adjustment of the internal parameters of the regulator, excessive predominance of the proportional part of the regulator over the differential part. This can be seen when comparing information about the control actions in the system and the movement of the drive.

As can be seen from the graphs in figures 7 and 8, the adjustment of the parameters positively affected the quality of the technological process. The obtained parameters can be used in the control system, making changes in the equipment settings and in the technological process map for the appropriate size of the waveguide connection. This approach will ensure high quality of serial production.

5. Conclusion

The problems of formation of an integral soldered joint of a waveguide channel using an induction heating source are considered. Structural and functional schemes of an automated system of experimental studies of such process are presented. The proposed system is implemented and tested. The application of the experimental research system allows one to search for suitable parameters of the technological process, as well as equipment settings in which it is possible to obtain a quality soldered joint.

6. Acknowledgments

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