DEVELOPMENT AND USE OF LASER TECHNOLOGIES FOR THE HEAT-EXCHANGE EQUIPMENT

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ABSTRACT
Features of technology of laser processing at production of different types of the heat-exchange equipment are considered. The technology of laser welding of edges and a sheet of panels of heat exchangers from stainless steel providing reliable and tight connection in the absence of considerable deformation is presented. The new design of a recuperator for mine furnaces allows to cut a consumption of coke to 30% and to considerably increase productivity and efficiency of metallurgical production. The manufacturing techniques with application of laser processing of the panel of the flexible heat exchanger of the ironing machine are developed. The technology provides a dense adjoining of the heat exchanger to the driving drum, the minimum thermal change of a form at a running cycle "heating-cooling" and high efficiency.

Keywords: laser technologies, production of the heat-exchange equipment

INTRODUCTION
Laser technologies find more and more broad application in various industries, one of which is production of the heat-exchange equipment.
In 2013 the mine furnace of Ufaleynikel enterprise has been equipped with a recuperator of a new design for air heating by flue gases (fig. 1, a). 633 "air" and "gas" panels have been manufactured of sheets of stainless steel C08Cr18Ni10Ti with using of the laser welding providing reliable and tight connection of edges and a sheet in the absence of considerable deformation (fig. 1, b).

![Fig. 1. A recuperator of the mine furnace (a) and the connection of edges and a sheet of the panel of the heat-exchanger manufactured by laser welding](image-url)
Total length of welds on each panel has made 75 meters, the weight of finished product is about 30 tons. The design allows to save from 20% to 30% of coke. The developed technology has no analogs, RCLT has taken out on it two patents (the Patent of Russian Federation No. 146292, 2014; the Patent of Russian Federation No. 2567936, 2015).

The entity of laser welding technology of the heat exchanger panels is that by means of welding on the laser technological Trumpf Laser Cell 1005 complex provides a welding of edges from stainless steel 1,5 mm thick to a sheet with the sizes of 2010 x 1170 mm from the same steel 1,5 mm thick.

Difference of this technology from the known technologies of welding of similar details is that at the expense of a special design of the welded details and the equipment (conductor), and also a careful selection of parameters of processing it was succeeded to achieve performance of a number of basic requirements of the customer:
- a dense contact of edges to the basis, a continuous weld and, respectively, good conditions of a heat transfer from edges to the basis;
- lack of openings in the basis and, respectively, lack of contact between various gas environments which are in the adjacent layers of the heat exchanger;
- the minimum thermal changes of a form ("deformations") of finished panels and, respectively, simplicity of assembly of modules of the heat exchangers which are structure from the alternating "gas" and "air" panels (fig. 2) laid over at each other.

Before welding by means of the “tenon - dap” connection preliminary assembly of panels was carried out: edges "were attracted" to the basis, as provided lack of intolerable gaps between edges and the basis.

Conductors (they were two: one was for "gas", another was for "air" panels) on which previously assembled panels settled down, provided reliable fixing of the processed assemblies (fig. 3). It has allowed to exclude deformation of panels in processing and to minimize their residual deformations (after extraction from the equipment).
Fig. 3. The finished "gas" panel on the equipment

Besides, a certain sequence of performance of continuous welds by means of a combination of the intermittent welds which are carried out with small overlapping "randomly" so that to provide symmetric thermal impact on the welded panel and its rather uniform heating has been applied to minimization "deformations" of panels.

The technology differs in high efficiency in connection with the high speed of laser welding. So, on the "gas" panel the sizes of 2010 mm by 1170 mm welded 37 edges 2010 mm long on the basis, on the "air" panel with the same sizes welded 65 edges 1170 mm long on the basis. That is the total length of welds on "air" and "gas" panels was approximately equal and has made about 75 m on one panel. Time of welding was also approximately equal and has made about 60 minutes on 1 panel. Time of reinstallation of panels on the equipment has made about 15 minutes.

The laser welding conditions of C08Cr18Ni10Ti stainless steel are investigated. Speed of welding of 6-8 m/min for sheets by thickness 1.5mm is experimentally established at the power of radiation of 5000 W, shielding gas is argon.

By request of "Kalugin" on the RCLT with application above the described technology 4 heat-exchange devices of plate type with sizes of panels of 500 x 985 mm (fig. 4) are manufactured. The new design of a recuperator for mine furnaces allows not only to cut a consumption of expensive coke to 20%, but also to considerably increase productivity and efficiency of metallurgical production. Introduction of this technology also promotes reduction of emissions in the atmosphere of carbon oxides, reducing an ecological pressure on the environment. The made recuperators are supplied on Chusovskoy metallurgical plant.
The RCLT has developed manufacturing techniques with using of laser processing of the panel of the flexible heat exchanger of the ironing machine within the import substitution program of machines of Jensen JenRoll Express (fig. 5) for the Southern Ural Railroad. The flexible heat exchanger represents an assembly and welded design from sheet and pipe rolled products of C08Cr18Ni10Ti stainless steel. A basic element of a design is the 1600 x 2750 mm heat-exchange panel manufactured with use of technologies of laser cutting and laser welding.

The design of the panel consists of two sheets of stainless steel 1.5 mm and 4 mm thick imposed one on another and welded on perimeter by a double tight weld from a thin leaf side. The thermal panel gets of the cylindrical form in the course of production. Then in a certain order in the field of a sheet welded "circles" (the closed circular welds with a diameter of 16 mm and 20 mm in
number of 1996 pieces) (fig. 6) are carried out. Due to the lack of standard rolled metal of necessary width a blank has been made of a 4 mm thick sheet by means of butt laser welding of two sheets.

![Fig. 6. Disposition of welded "circles" on the panel](image1)

Welding of the panel of the heat exchanger is made on the laser TLC 1005 complex of TRUMPF the radiation of 5 kW (welding of circular welds) and on the robotic laser FLW-10-01 complex as a part of the 10 kW fiber laser of production of "IRE-Polus" and the KUKA KR120 robot (welding of the 4 mm thick blank).

Upon completion of welding of sheets on perimeter and circular welds, through technological openings between sheets liquid under the high pressure which, deforming a thin sheet, forms a cavity for pumping heated to 240 °C steam is pumped. After final assembling of pipelines the heat-insulating "ARMOR" covering on the basis of nanopowder (fig. 7) is applied on the workless surfaces of the heat exchanger.

![Fig. 7. Assembling of pipelines and applying of a "ARMOR" nanocovering](image2)
Advantage of the offered design of the panel of the heat exchanger consisting of stainless steel consists in lack of galvanic corrosion unlike a similar import design where one of sheets is carbon structural steel (fig. 5).

Difference of this technology from the known technologies of welding of similar details consists in a small heat input at laser welding and in the minimum buckling. Thanks to the careful selection of parameters of processing and the special equipment (conductor) it was succeeded to achieve a close-tolerance fit of the heat exchanger to the leading drum. Lack of effect of bimetal minimizes thermal changes of a form at a running cycle "heating - cooling" of the heat exchanger.

For minimization of thermal changes of panels continuous welds have replaced with short welds with small overlapping. Welding of "circles" was made in a certain sequence for ensuring uniform heating of the panel. The considered technology differs in high efficiency as a result of the high speed of laser welding.

The approval tests which have passed at the end of 2016 have confirmed high quality of the performed works, the heat sink coefficient completely corresponded to calculated values. It allows to organize production of similar heat exchangers and their replacement parts instead of import. By results of operation of the heat exchanger the contract for delivery of three more panels for the Southern Ural railroad is signed.

The developed technology can find broad application in metallurgical, power, agricultural, chemical and petrochemical mechanical engineering, in the food industry (the refrigerating equipment) by production of big scale of the heat-exchange equipment manufactured of stainless steels and titanium alloys.

Production of the heat-exchange equipment is very perspective area of laser technologies.

**Fig. 8.** Heat exchanger, ready to shipment

Now there are no Russian standards on use of laser welding technology of materials. In this regard the RCLT has carried out a complex of mechanical tests of models of laser welds from C0.12Cr18Ni10Ti steel. Results of tests have shown full compliance to requirements to the welds put in technical documentation on a product.