DEVELOPMENT OF TECHNOLOGICAL EQUIPMENT FOR LASER WELDING OF THIN-WALLED JOINTS FROM CORROSION-RESISTANT STEELS

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Based on the known problems of laser welding of thin-walled flat and cylindrical products made from corrosion-resistant steels, auxiliary technological equipment, consisting of a clamping conductor and a precision rotator, was developed and manufactured. The technological equipment has been tested. The results of the research have shown that the presented technological equipment provides high-quality, non-defective welded joints.

Keywords: laser welding, technological equipment, thin-sheet materials, corrosion-resistant steels, AISI 304, current issues, girth welded joints

Introduction. Laser welding is one of the most promising methods of joining materials, providing high productivity, precision, and quality of welded joints while reducing costs and efficiently utilizing resources. Due to minimal thermal impact and high process speed, this technology significantly increases the competitiveness of enterprises in such industries as nuclear, aviation, automotive, space, shipbuilding, and other areas [1]. One particularly relevant use of laser welding is related to joining of thin-gauge corrosion-resistant steels. Despite its obvious advantages, the use of laser welding for thin-walled parts is accompanied by a number of specific technological difficulties. Based on an analysis of scientific sources and the practical experience of the authors [2], the most characteristic problems of laser welding of thin-walled parts that need to be solved were identified:

1. Edge alignment. Insufficient contact or gaps between the welded surfaces can lead to incomplete fusion, defects in the welded joint, and reduced strength.

2. Clamping of parts. When clamping the parts to be welded, there is a high probability of bending in the center of a flat part, which may result in misalignment of the welded edges and the formation of non-fusion defects.

3. Heat dissipation. Due to the small thickness of the material, excessive heat input can cause local overheating and burn-through defects, as well as residual stresses and deformations of the welded part.

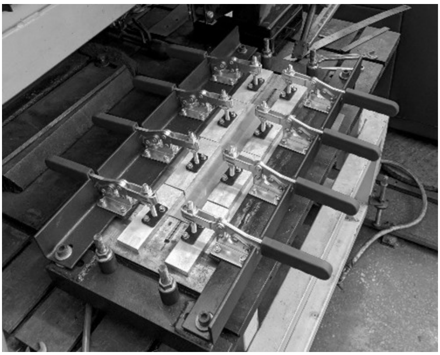
4. Gas protection of the welding zone. Inadequate gas protection can lead to creation of pores, color variations, and oxidation of the weld, which negatively affect the mechanical properties of the joint.

5. Difficulty in forming a weld on the substrate. For a complete weld, it is necessary to ensure that the laser radiation is removed from the reverse side of the welded joint.

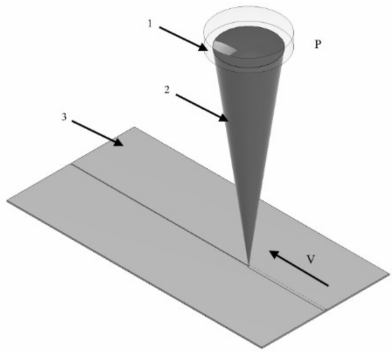
6. Formation of craters and metal deficit in the welded joint. When welding thin-walled parts with an axis of rotation, metal deficit often occurs, leading to a decrease in the tightness and durability of the joint, as well as the formation of craters at the beginning and end of the welded joint.

Presentation of the main material. To solve the aforementioned problems, auxiliary technological equipment, consisting of a clamping conductor and a precision rotator, was developed and manufactured.

The clamping conductor has a modular design and allows welding of parts up to 450 mm long (Fig. 1). The base has a channel with copper inserts to provide gas protection for the back side of the welded joint. The frame has 8 clamps with plates that allow for adjustment of the clamping force for each zone, ensuring that the edges being welded are clamped evenly along the whole length of the part.



a

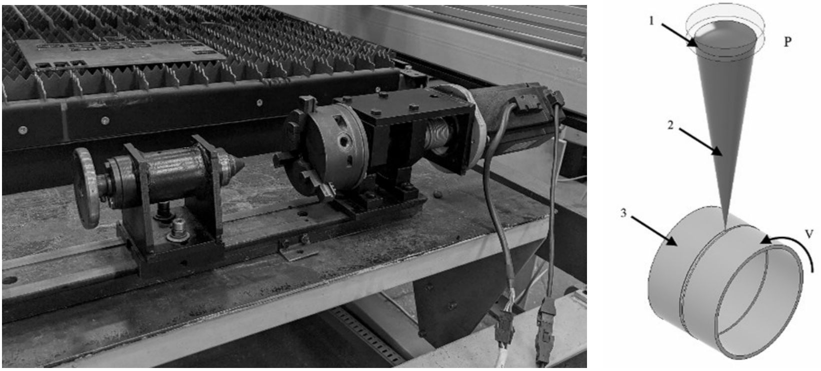


b

Fig. 1. a - Clamping conductor for laser welding, b - welding scheme utilizing the clamping conductor, where 1 – lens, 2 – laser beam, and 3 – welded part.

To test the clamping conductor, laser welding was performed on 300×100×1.5 mm samples of butt joints made out of AISI 304 steel. The edges to be welded were prepared by milling. The welded joints were certified by visual inspection for defects in accordance with DSTU EN ISO 13919-1:2015. The possibility of formation of following defects was checked: lack of fusion, incomplete penetration, undercut, excessive convexity and burn-through, metal leakage, concavity of the weld root, its undercut, and metal spatter. Based on the results of visual and X-ray inspections, none of the above defects were found.

A precision rotator with integrated servomotor control has been developed for the laser welding machine control system for welding of ring welded joints with a rotation axis that would allow for positioning accuracy of up to 0.1 mm, as well as repeatability within ±0.08 mm for welded parts with diameters of 6–90 mm (Fig. 2).



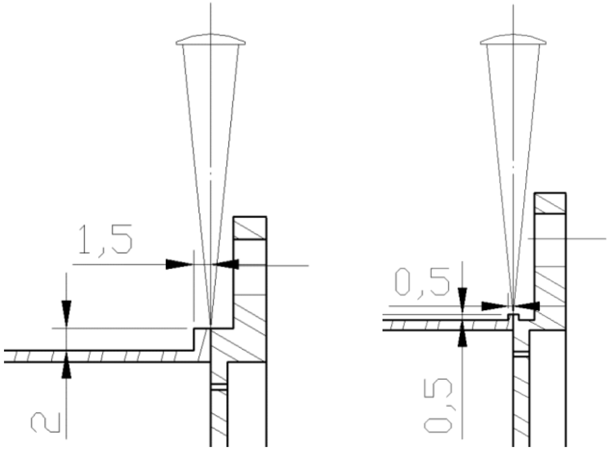
a b

Fig. 2. a - Precision rotator, b - Welding scheme on a precision rotator, where 1 – lens, 2 – laser beam, 3 – welded part.

To test the precision rotator, laser welding of ring welded joints of a thin-walled sensor body made of AISI 304 corrosion-resistant steel was performed. Welding was performed in pulse mode at a frequency of 1000 Hz and a maximum laser power of 200 W. High-purity argon with a flow rate of 12 l/min was used as a protective gas for the welding zone. To prevent the formation of craters at the start and the end of the joint, a method of gradual increase and later decrease of the radiation power was used. The first design scheme for the welded joint was a "flanged cover" configuration, where the flange was formed directly on the cover of the sensor part (Fig. 3, a).

After welding, depressurization in the sensor contact area of the flange was detected, caused by local overheating due to the excessive volume of remelted metal. To eliminate this defect, the geometry of the edges was changed and additional cooling on the side of the housing, where the contacts are attached, was provided. In the next iteration, flanges were formed on both the cover and the flange in the form of 0.5×0.5 mm external flanges (Fig. 3, b).

To dissipate heat from the contacts, an aluminum spacer with thermal paste was used, which was pressed from the flange side. To reduce friction between the spacer and the rear cap, a metal ball was installed in a special groove. As a result of welding, a sealed connection was obtained without local overheating. As a result of the conducted laser welding experiment, it was possible to form a high-quality and sealed welded joint without local overheating of the surrounding metal and the sensor mounting area in the flange.



a b

Fig. 3. Schemes of welded edges a - “cover with flange” and b - “cover and flange with flanges” of the sensor housing.

Conclusions. Auxiliary technological equipment for laser welding of thin-walled flat and cylindrical products made from corrosion-resistant steels has been developed and manufactured. The results of experiments have shown that the presented technological equipment solves the current problems of laser welding of thin-walled corrosion-resistant steel products and ensures the production of high-quality, non-defective welded joints.

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