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R. Kocurek*, J. Adamiec

Silesian University of Technology, Department of Material Science,
Faculty of Material Science and Metallurgy, Katowice, Poland
** robert.kocurek@polsl.pl*

MANUFACTURING TECHNOLOGIES OF FINNED TUBES

ABSTRACT

The increase in demand for electricity in Europe requires a continuous search for new sources of energy, engineering and technology solutions. Maintaining the current level of electricity production requires not only repair and modernization of the operating units, as well as construction of new blocks of supercritical and ultra-supercritical. Increasing thermal efficiency while reducing energy costs is possible through the use of finned tubes for heat exchangers. This paper presents the technologies of finned tubes, with particular emphasis on innovative laser welding technology developed in the Energoinstal SA company. The use of high power disk laser allows the welding of finned tubes several times more efficient compared to arc welding technology, while maintaining stringent quality and technical requirements.

Key words: *finned tubes, laser weldings, power boiler, energy efficiency*

INTRODUCTION

Improving energy efficiency is one of the main pillars of energy security and improve the competitiveness of the European economy [1,2]. The growing demand for electricity and the conditions of European Union directives impose modernization of the energy industry. This makes it necessary to take action in terms of design, technology, manufacturing and operation of power plants, as well as finding new sources of renewable energy [2].

One of the directions of improving the efficiency of gas power plants is the use of finned tubes. Finned tubes with continuous rib or serrated, depending on the operating parameters of the working medium and the flue gas can be used as: heaters, economizers or superheaters (Fig. 1). The fins greatly enhance the heat transfer surfaces, allowing the full optimization of heating surfaces of the boiler, which is achieved by reducing the dimensions of the boiler, and thus reducing its weight. The efficiency of the heat exchanger tube depends on the thermal conductivity between the pipe wall and the fluid and the surface area of the tube. For pipes of the finned heat exchanger surface can be increased by 30 times compared to the finned tube is not, and thus significantly increases thermal conductivity and the heat flux per unit increased by almost 300% as compared to compared to smooth pipes, leading to an increase in overall efficiency of industrial boilers.

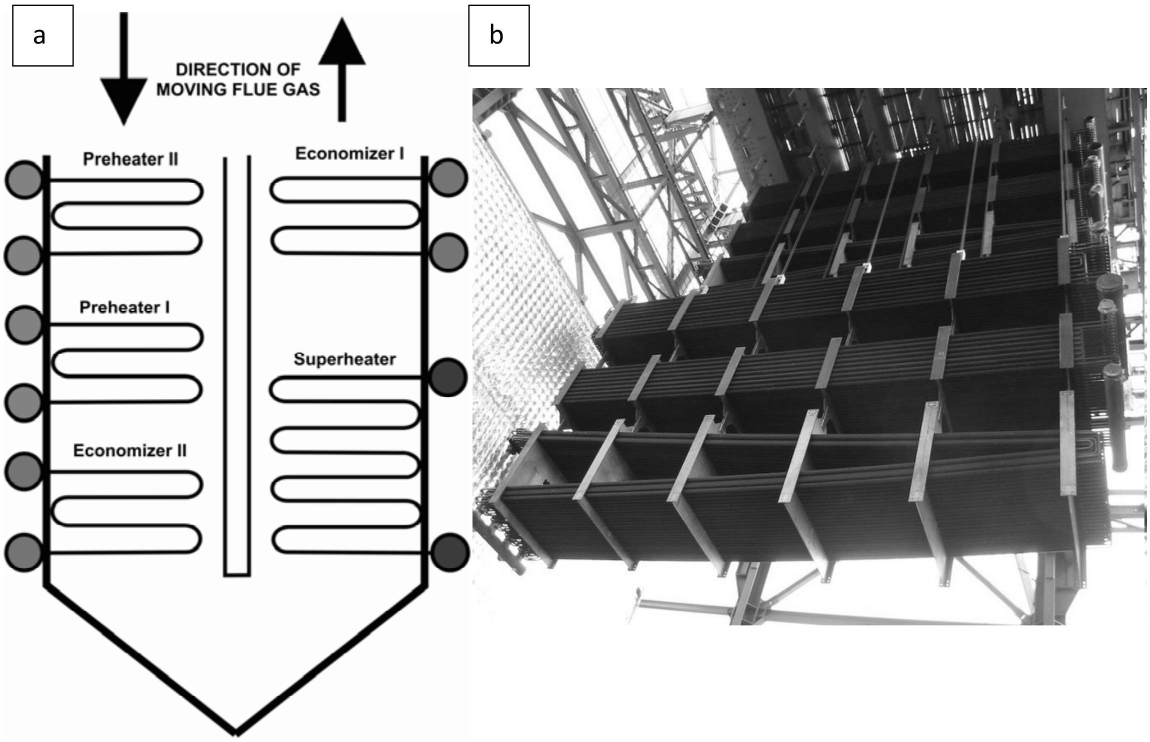

Fig. 1. Diagram of a typical industrial boiler working parts (a), a set of heat exchangers with finned tubes (b) [3]

Manufacture heat exchangers with finned tubes, due to the increasing competition requires the implementation of new technological solutions in the production area. The basic technology of finned tubes should include rewinding the tape directly on the pipe, mechanical crimping wound strip production process wrought with high frequency welding and arc welding, mostly MAG. Tubes with tape or tape wound kneaded not be used in power because of the shared structure that does not provide a sufficiently good conditions for heat transfer. In addition, over time the quality of the connection service falls under the influence of thermal expansion and vibrations, which results in deterioration of thermal efficiency [4]. In modern gas boilers are increasingly being used finned tubes made in the technology of laser welding. The use of concentrated laser beam power allows for a significant increase in connection speeds, ensuring the quality of the connection required by the technical regulations and standards.

MANUFACTURING FINNED TUBES IN THE PLASTIC WORKING PROCESS

The oldest patented method of producing cross-finned tube with a full connection is a plastic working. In the process of cold rolling formed monometallic and bimetallic tubes. For the production of pipes are used triaxial angular contact rolling (Fig. 2a). Each roll contains the right amount of disk utilities variable geometry part of the work, and on the number of fins per meter depends on their thickness. In this technology can be divided into two types: depressing and grading method. Depressing method involves inflicting deformation using the tool disk of increasing diameter and height of the ribs is achieved by a gradual penetration of the surface pressure and the working tools. This technology is used for the production of low-finned tubes. In method grading with strong clamps and tools for working with thicker walls of the tube base is obtained while thinning the cross ribs and increase its diameter. This method is applicable to the production of high-finned pipes (Fig. 2b).

The materials used in the production of bimetallic pipes on the base pipe can be continuously boiler, austenitic stainless steel, brass, copper and its alloys, while the external fins of the tube is used in aluminum, copper and their alloys. Due to the differences in the thermal properties of the materials used pipe can be applied to most chemically aggressive media and the operation to a temperature of 200 ° C [7,9].

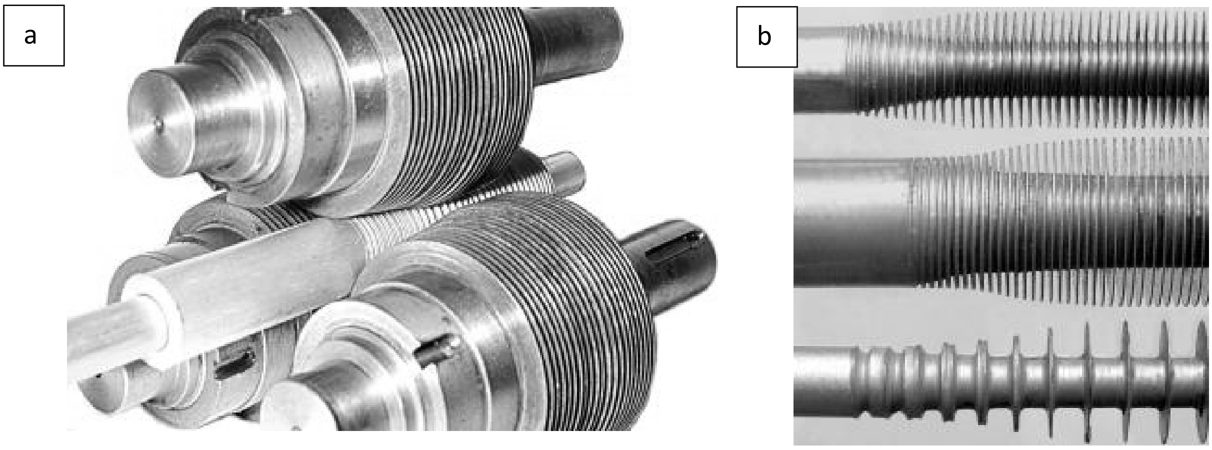

Fig. 2. The manufacturing process of finned tubes: a) a set of three rolls of rolled tube, b) high finned tubes manufactured by depressing and grading [9]

Another method of manufacture of finned tubes is to use the hot rolling process. This technology involves winding the tape and clamping it in before the notched groove in the base pipe (Fig. 3a). Difficulties occur in the production of stainless steel pipes. Willing stainless steel to strengthen is much higher and the groove in the base pipe cause a reduction of its thickness, which makes the production of pipes in this technology becomes uneconomic. In the case where the base pipe is made of ordinary steel, the wall thickness does not significantly affect the price of the heat exchanger. Finned tubes produced with this technology are applied to a temperature of 450° C in the case of aluminum fins and 500° C in the case of stainless steel ribs [7,8].

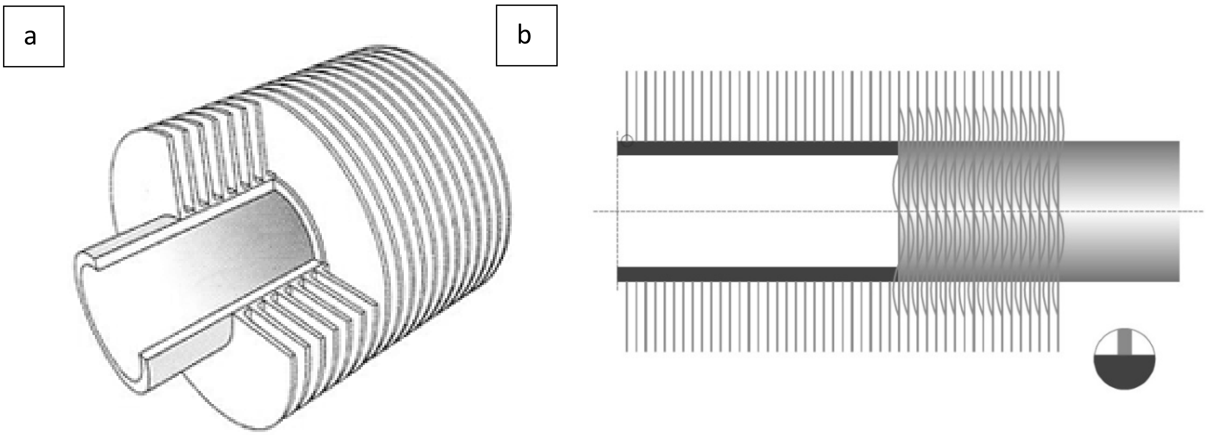

Fig. 3. Examples of finned tubes produced: a) finned tube type G, b) finned tube type Z [8]

Another manufacturing technology finned tubes is applied to the base pipe and the webs of sheet welding or soldering the ends of the tube webs (Fig. 3b). The configuration webs creates a form of a helical spring, which is tightly applied to the pipe acts as a heat sink. Dissolve the sheet in this manner causes the tape is heavily creased, thereby increasing the contact area between the base of the finned tube and the thermal surface and the air flowing over the turbulent motion. For the production of such pipes can be used, almost all commercially available materials [9].

WELDING TECHNOLOGIES FINNED TUBES

Due to the low efficiency of cross-finned tube heat caused by the lack of a lasting connection with a rib metal pipe, production technologies have been developed using welding techniques. Currently, the production of finned tubes used shielded welding consumable electrode active gas (MAG) and welding with a laser beam, which has contributed to a significant increase in the efficiency of the production process. Another variation is to connect pipes with fins welded high-frequency currents.

The most commonly used in industrial manufacturing technology finned tubes is an automatic welding consumable electrode active gas welding (MAG). Connecting the ribs with the pipe is done using a fillet weld (Fig. 4) or by performing a joint front in the ribs (Fig. 5). The first method has a relatively low yield (linear welding speed 2 m / min). However, in the case of the second technology cannot guarantee sufficiently high quality for use of connectors, due to the incompatibility unacceptable welding, such as lack of fusion, adhesion, flooding and splashes (Fig. 5b).

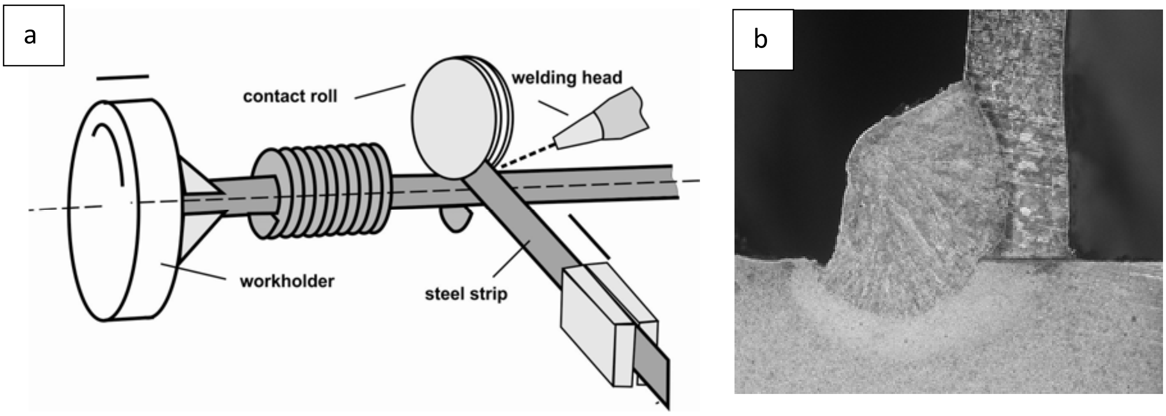

Fig. 4. Welding finned tubes fillet weld: a) diagram of the process welding, b) the joint weld pipe - rib area (magnification 5x)

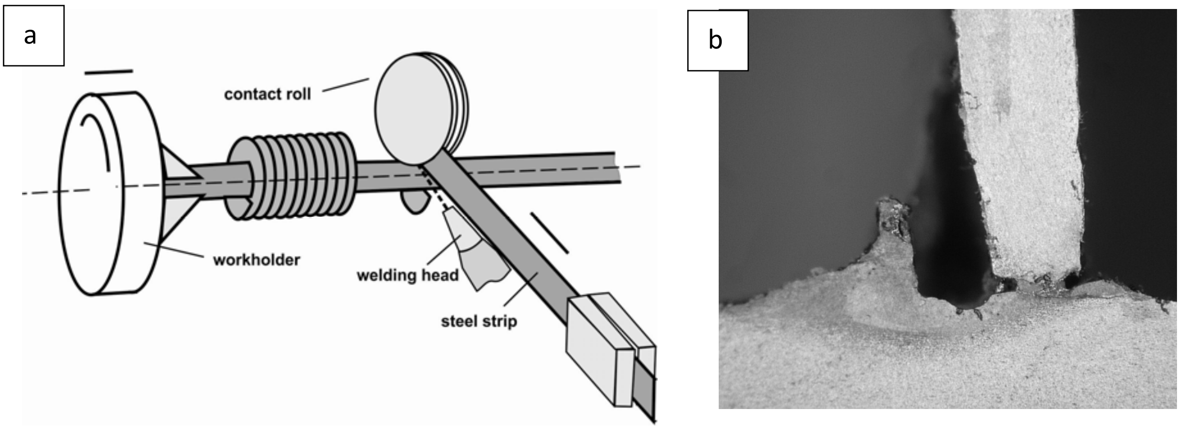

Fig. 5. Welding finned tubes in the ribs: a) a diagram of the process pipe welding in the ribs, b) butt joint pipe - rib, ribs visible separation, magnification 5x

Welding contact currents frequency (HF) is a variation of resistance welding which uses a high-frequency properties of the welded contact surface heating elements to melt temperature, and combinations thereof by pressure (Fig. 6). In this method, it is important to fine-tune current switch position. The typical non-compliance include local burnout and flooding the surface of objects and weld splatter of molten metal.

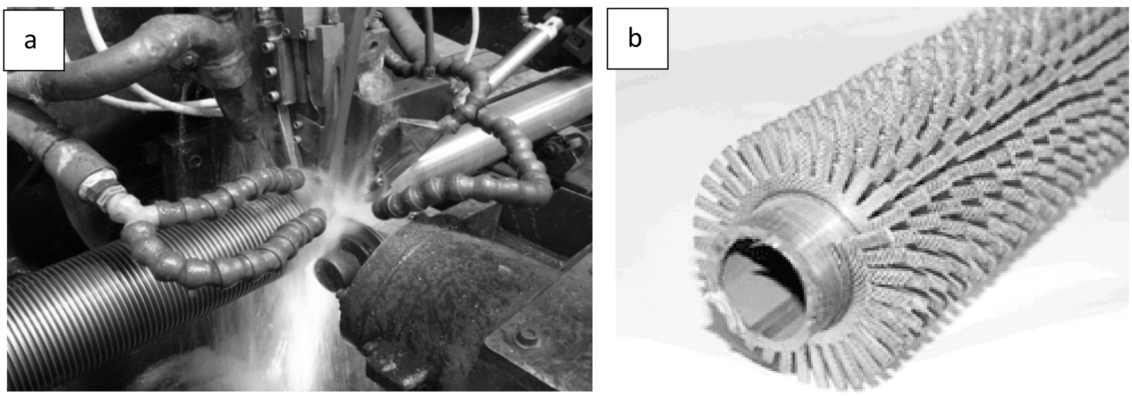

Fig. 6. The welding process currents of high frequency (HF) of finned tubes (a) [12], the pipe is made with the rib serrated HF technology. (b) [13]

INNOVATIVE TECHNOLOGY LASER WELDING FINNED TUBES

Technological advances in modern production methods and the growing demand and requirements of investors made people look for more efficient production technology finned tubes. An alternative for the production of welded finned tubes with conventional bonding technology can be laser welding.

Currently, lasers are used for welding of boilers for power, for reasons of the limited power of the beam, the difficulty of precise preparation of the connector, the ability to cure both in a narrow heat-affected zone and the weld seams and the tendency for hot cracking. However, the advantages of disk laser, in particular the stability of the welding process, the increased tolerance of joint preparation, welding high energy density and a significant increase in productivity are causing that these technologies are an important direction of development of the process of joining materials for energy.

In company Energoinstal SA have been attempts to weld pipes with fins on an innovative position for automatic laser welding, consisting of a laser disk TruDisk 8002 Trumph of the system of distribution of the laser beam into two welding stations equipped with systems on the market and the feed pipe welding and automatic painting. Welding schematically shown in Figure 4a.

Laser TruDisk 8002 is equipped with two optical fiber length of 30 m, which in combination with two heads welding allows welding alternating on each line position. This arrangement will maximize the use of the laser. When welding on line 1, the second line it takes to prepare the next pipe. Tube transport system enables the movement of the linear speed of 5 m / min (Fig. 4c). Welded pipe length range is from 3 m to 24 m, while keeping runs from 50 mm to 250 mm.

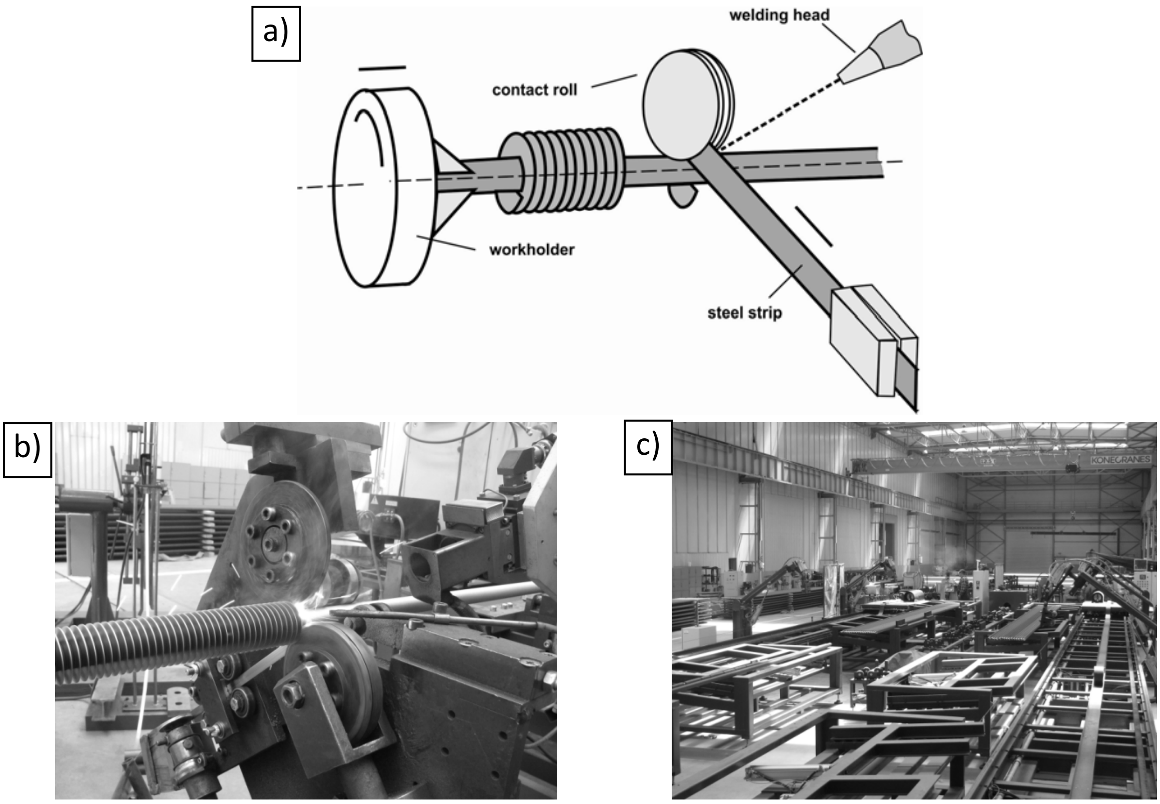

Fig. 7. Laser welding station finned tubes developed Energoinstal SA: a) general scheme of the welding, b) running back position, c) general view of the position

An important factor in the possibility of welding finned tubes at speeds up to 200 rev / min (linear welding speed about 24 rpm). the welding head positioning system (Fig. 4b). In Energoinstal SA triaxial system was designed with continuously adjustable in each axis, which resulted in the possibility of: adjusting the position of the laser head, automatic tacking strips before welding and automatic cutting the tape at the end of the laser beam welding process. In order to heat pipes before welding the induction heating system is designed to pipes for heating the gas allows for the full control and the control of the preheating temperature. The system is integrated with the entire line and allows the heating pipes with a diameter of ϕ 44,5 and a wall thickness of 5 mm and a temperature of 300°C, the linear velocity of the feed 5 rpm. The advantage of the proposed solution over the currently used is the ability to apply it to high-welded finned tubes (eight-fold increase in performance over MAG welding), while complying with all the requirements of technical regulations.

The tests were performed Energoinstal SA laser welding steel pipes P235GH with a rib X2CrTi12 serrated steel beam with a capacity of 4 to 4.5 kW. Tube rotational speed is in the range from 100 to 250 rpm, welding performed in argon at a flow rate of 5 l/min.

Visual examination performed according to standard PN-EN ISO 17637 has shown that the joint is continuous along the entire length of the pipe (Fig. 8a). Weld is characterized by a smooth grains and full penetration (Fig. 8b). On this basis, welded joint qualified to the quality level B according to PN-EN ISO 13919.

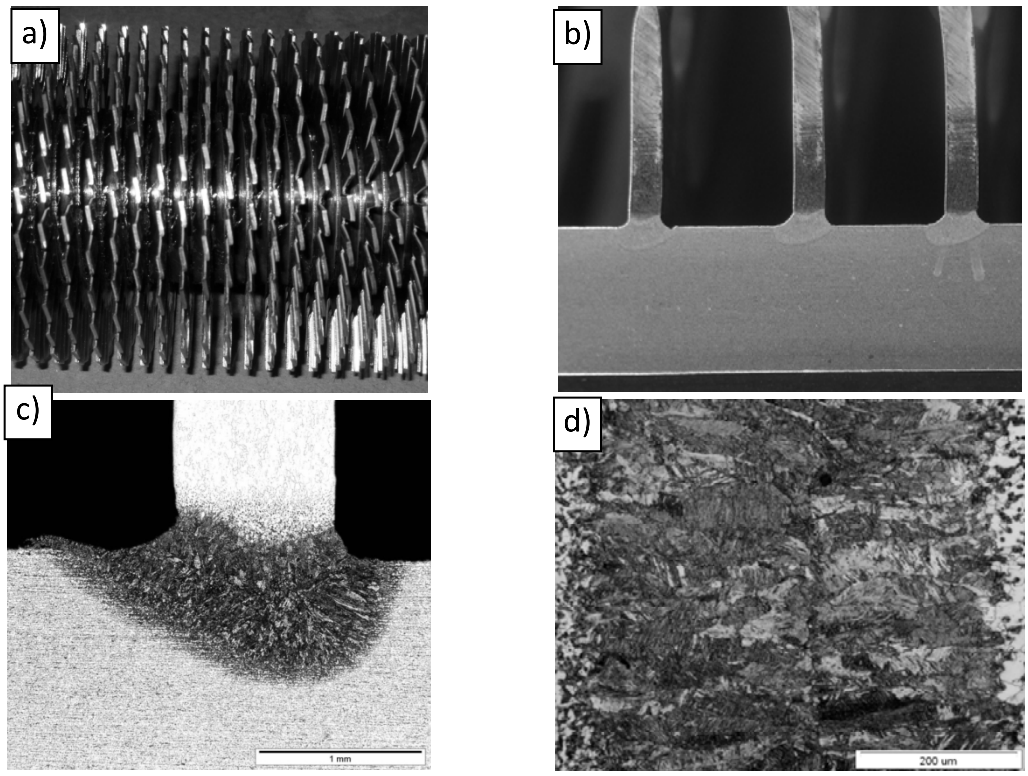

Fig. 8. Laser-welded finned tube with serrated rib (s), macrostructure welded joint made of laser power of 4 kW at 150 rpm (b), the microstructure of joint P235GH + X2CrTi12 (c), the structure of joint (d).

Analysis of the microstructure of the welded joint (Fig. 8c) showed the presence of ferritic-martensitic structures of narrow heat affected zone (50 - 100 μm) (Fig. 8c) and martensitic in the joint (Fig. 8d). Measurements made by the Vickers hardness at a load of 9.8 N (HV1) revealed no increase in the hardness of the connection above required by the standard PN-EN 15614-11 level of 380 HV (Fig. 9).

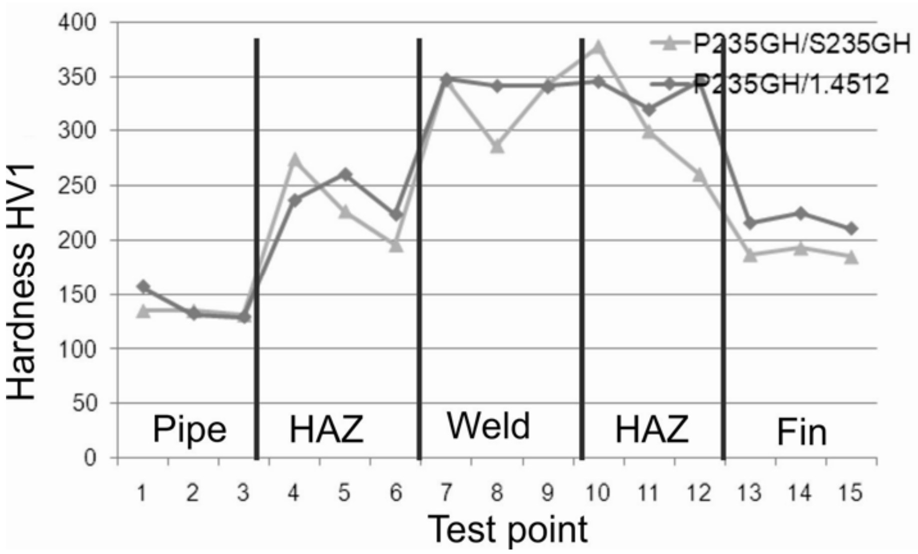

Fig. 9. Distribution of hardness in the connector tube-fin made in laser technology

Complementing assess the quality of the connection tube-flat bar technology peel test was ribs. The samples were prepared rib fragments of pipe joint, which cut production tubing. The tensile test was performed on the company Cometech in brackets that allow attachment of the sample perpendicular. The sample before stretching shown in Fig. 10a, and Fig. 10b shows the samples after static stretching. It was found that in all tested combinations rupture occurs outside the terminal, indicating that the strength of the connection is greater than the strength of the ribs. Thus, a combination of laser tube made of flat bar meets construction requirements.

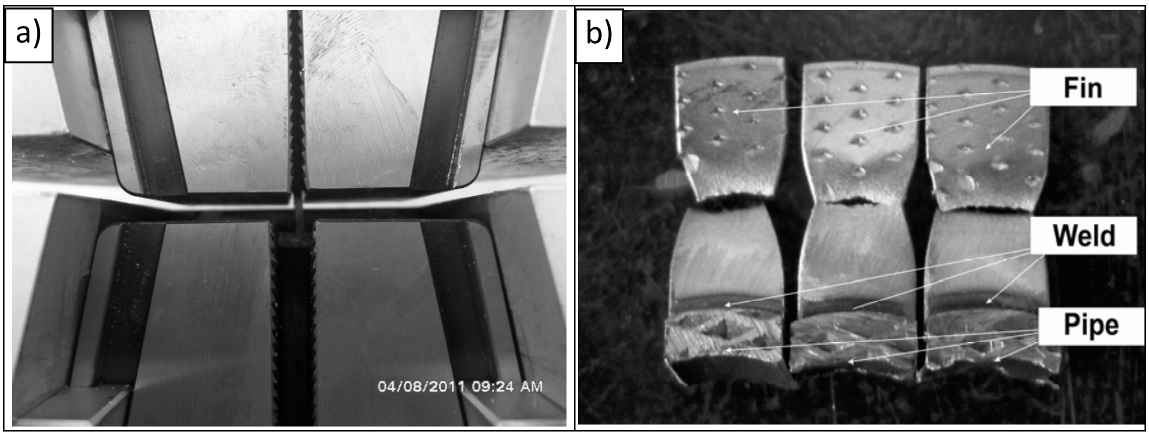

Fig. 10. Results of trials are static tension-rib pipe connections: a) position in grip of testing machine, b) specimen after testing

The study of structural and hardness measurements have shown that laser welded joints tubes flat bar (rib) meet the quality level B according to PN-EN ISO 13919, so the technology can be classified according to with PN-EN ISO 15614-11.

SUMMARY

The use of welded finned tubes in the power equipment leads to savings in energy and cost savings in the operation of industrial boilers, heat recovery condensing and its deliberate use and minimize energy losses by lowering the temperature of the flue gases. There are several technologies for production of finned tubes for the energy industry. The most important of these include the production of plastic working process, high frequency welding, arc welding, MAG welding process. These methods, despite its advantages, which include first of all a combination of continuous tube-fin, which significantly increases the thermal efficiency, characterized by low productivity and the possibility of the occurrence of imperfections such as: incomplete fusion, no weld penetration, spatters, etc.

In the company Energoinstal SA has developed an innovative technology for high-performance laser welding finned tubes, which ensures a level of quality welded joints PN-EN ISO 13919, with an eightfold increase in production efficiency.

Made welded joints are characterized by continuous full penetration weld the entire length of the pipe joint hardness does not exceed 380 HV, which indicates that this technology can be qualified by the Society of Notified Bodies for use in the energy industry.

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