

Abstract

The Welding of Two-Layer (Composite) Tubes with the Use of Laser Technology [†]

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Welding technologies are the most popular technologies used in the joining of steels. Increasing demands concerning the quality of welded joints and the need to increase the efficiency of the welding process force designers and technologists to look for new and innovative joining methods [1].

Power generation is one of the most important sectors for the economy. Today, innovative materials and technologies are key elements of power generation development [2].

The development of new-generation steels is closely linked to the ever-growing power industry. The elements of power boilers are protected against the aggressive effects of combustion products by ceramic liners or overlay welds characterized by high corrosion resistance and heat resistance. Flue gases formed during waste combustion contain very aggressive and environmentally harmful compounds, including sulphides, chlorides and fluorides [3,4].

To date, the most popular process used in the power industry to increase the durability of boiler components involves surfacing the latter with nickel-based alloys. Nickel alloys are characterized by very good service properties. The above-named materials are resistant (within a wide temperature range) to the effects of a corrosive environment, and, in particular, to pitting as well as intergranular and crevice corrosion [5].

Another solution applied to protect boiler components from the aggressive effects of combustion products is the use of double-layer tubes (commercially referred to as composite tubes).

A two-layer tube is used where conditions outside and inside the tube require properties which cannot be provided by only one material. Such a tube consists of two different alloys combined metallurgically to achieve good heat transfer properties. One alloy is used to resist corrosion, while the other is tasked with preventing creep processes [5,6].

This paper presents the results of research concerning the application of laser welding technologies used for the butt joining of double-layer tubes. The tests were carried out on 3R12/4L7- and Sanicro 38/4L7-grade two-layer tubes produced by Alleima (Table 1).

The research also included the adjustment of the parameters of the laser welding of the inner layer (steel 4L7—1.0425) and the hybrid welding (laser + MAG) and surfacing of the outside layer (steel 3R12—1.4301, steel Sanicro 38—2.4858) [7,8].



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Table 1. Chemical composition of 3R12/4L7 and Sanicro 38/4L7 double-layer tubes [5].

Tube	Chemical Composition							
	C	Si	Mn	Cr	Ni	Mo	Cu	Ti
4L7 (P265GH)	0.18	0.30	0.69	0.14	0.25	0.04	0.030	0.005
3R12 (AISI304)	0.008	0.36	1.11	18.22	10.04	0.24	0.26	0.004
Sanicro 38 (Alloy 825)	0.012	0.15	0.47	19.92	38.24	2.57	1.61	0.75

The welding of the double-layer tubes was carried out in two steps [9]. First, the inside layer of the tube (4L7) was made with a beam of laser radiation (without the filler metal; Figure 1). The parameters of the laser welding process for the inside layer of the tube are presented in Table 2.

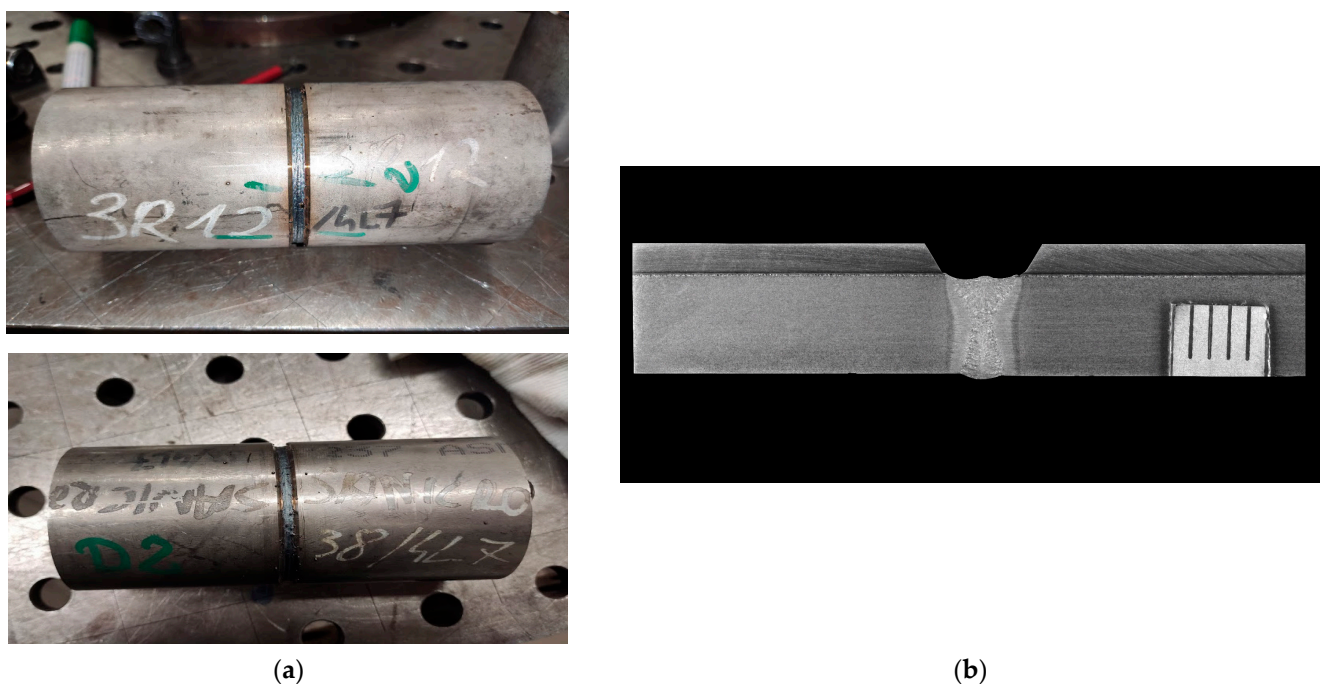


Figure 1. Laser welding of the inside layer of the tube: (a) joint (3R12 and Sanicro 38 tubes) viewed from the face side and (b) macrostructure.

Table 2. Parameters of the laser welding process of the inside layer of the tube (steel 1.0425).

Welding Parameters	Inside Layer (Steel 1.0425)
Laser power (kW)	4.5
Welding rate (m/min)	0.8

The second stage of the process involved hybrid surfacing [8] with the use of the filler metal (3R12, Sanicro 38, Figure 2). The parameters of the welding process and the hybrid deposition (laser + MAG) of the outside layer are presented in Table 3.

The research revealed that the laser welding method used to join the test tubes (4L7—inside layer) made it possible to obtain quality butt joints with a uniform face and properly formed root (meeting the requirements of quality level B according to ISO 13919-1) [10].

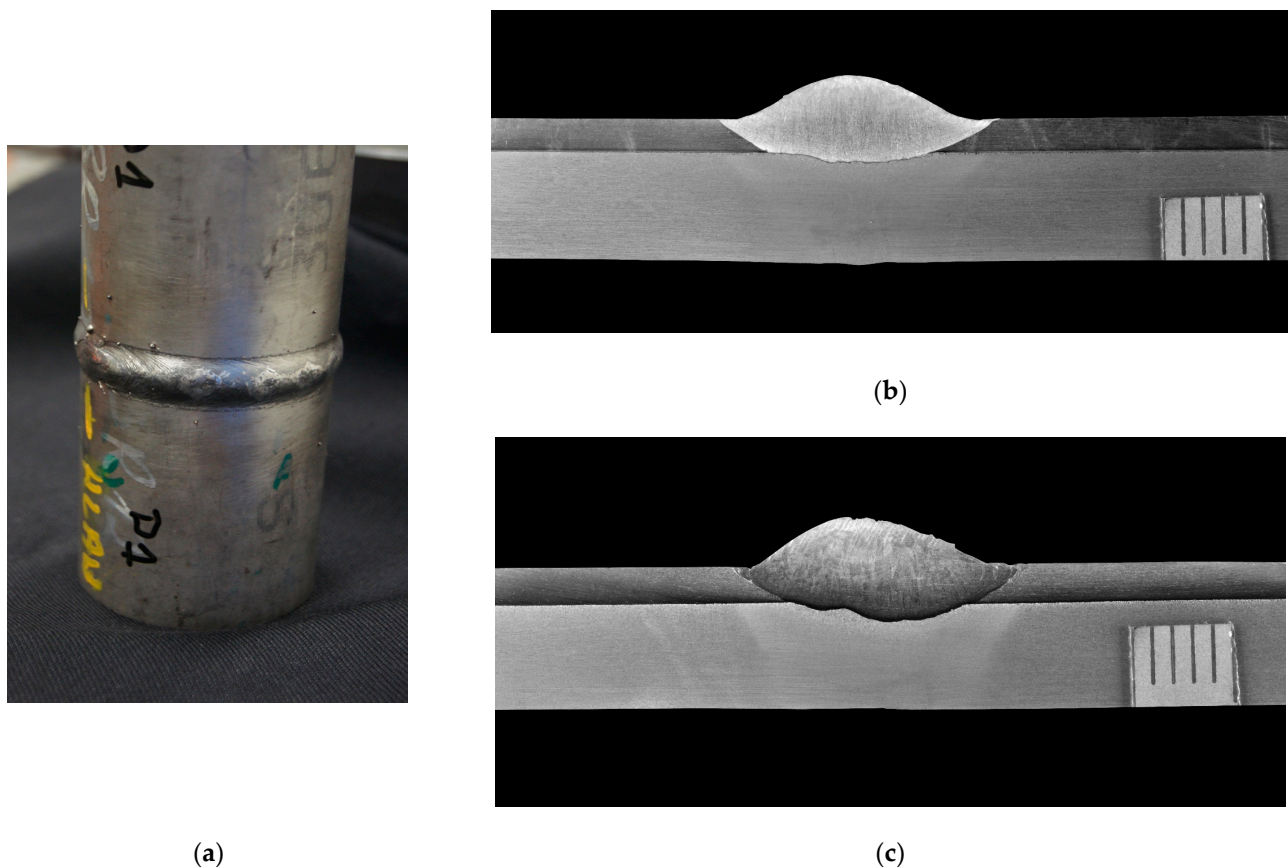


Figure 2. View of the joint after the welding process and hybrid deposition (laser + MAG): (a) view of the surfacing from the face side (3R12 tube), (b) macrostructure of 3R12 tube and (c) macrostructure of Sanicro 38 tube.

Table 3. Parameters of the welding process and hybrid deposition (laser + MAG) of the outside layer (3R12, Sanicro 38) with the use weave seam double triangle.

Welding Parameters	Outside Layer (Tube: 3R12, Sanicro38)
Laser power (kW)	0.5
Welding rate (m/min)	0.3
Filler metal wire feed rate (m/min)	8.5
Weave amplitude (mm)	6
Weave length (mm)	1.5

The use of the hybrid surfacing process for the deposition of the outside layer of the pipe enabled the obtainment of an overlay weld with a properly shaped face (meeting the requirements of quality level B according to ISO 12932) [11].

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References

1. Brian, M. *Victor Hybrid Laser Arc Welding*; Welding Fundamentals and Processes; Edison Welding Institute, ASM: Almere, The Netherlands, 2011; p. 6A.
2. Directive 2014/68/EU of the European Parliament and of the Council of 15 May 2014 r, Official Journal of the European Union L189/164. Available online: <https://eur-lex.europa.eu/eli/dir/2014/68/oj> (accessed on 20 May 2024).
3. Hernas, A. *Żarowytrzymałość Stali i Stopów*; Wydawnictwo Politechniki Śląskiej: Gliwice, Poland, 1999.
4. Adamiec, J. High temperature corrosion of power boiler components clad with nickel alloys. *Mater. Charact.* **2009**, *60*, 1093–1099. [[CrossRef](#)]
5. Sandvik 3R12/4L7, Sanicro 38/4L7 “Composite Tubes for Recovery Boilers and Other Boiler Applications”, Alleima (Sandvik Materials Technology). 2023. Available online: <https://www.alleima.com> (accessed on 10 June 2024).
6. Lalik, S.; Adamski, J.; Balcerzyk, A. Welding of Gas-Tight Pipe Walls Made of Composite Pipes of 3R12/4L7 Steel. *Solid State Phenom.* **2016**, *246*, 197–200. [[CrossRef](#)]
7. Ciokan, R. Urbańczyk M. Lisiecki, A. The Development of a Technology of the Laser-Based Welding of Butt Joints in Composite Tubes. *Bull. Inst. Weld.* **2021**, *1*, 23–31.
8. Urbańczyk, M. Hybrid Surfacing: Laser + MAG Electric Arc. *Bull. Inst. Weld.* **2020**, *6*, 22–37. [[CrossRef](#)]
9. Urbańczyk, M.; Adamiec, J. The Welding of Two-Layer (Composite) Tubes with the Use of Laser Technology. In Proceedings of the 4th Edition of International Conference on Materials Science and Engineering, Materials 2023, Singapore, 13–15 March 2023.
10. *ISO 13919-1*; Electron and Laser-Beam Welded Joints. Requirements and Recommendations on Quality Levels for Imperfections. Part 1: Steel, Nickel, Titanium and Their Alloys. International Organization for Standardization: Geneva, Switzerland, 2019.
11. *ISO 12932*; Welding. Laser-Arc Hybrid Welding of Steels, Nickel and Nickel Alloys. Quality Levels for Imperfections. International Organization for Standardization: Geneva, Switzerland, 2013.

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