

# STUDY ON THE EFFICIENCY OF SPOT WELDING TECHNOLOGIES FOR STAINLESS STEEL THIN SHEETS USING CONCENTRATED ENERGIES

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**ABSTRACT.** In the field of welding technologies, the nonconventional approach brings great progress, based on the results of scientific research in the field. Controlled energy concentration helps a lot to increase technological performance while significantly reducing processing costs, especially by making equipment designed in a new vision, in line with new developments in other fields related to welding, such as electronics, electrical engineering and IT methods for intelligent assistance / monitoring of operations performed. The present experimental research draws attention to the application of the WIG (TIG) process in a temporary joint application (spot welded) of thin stainless-steel sheets, in optimal precision and economy conditions.

**KEYWORDS:** temporary joint, concentrated energy, unconventional, thin sheets, economy, precizion

## 1. INTRODUCTION

Concentrated energies are an essential feature of unconventional technologies [1]. The creation of non-removable joints of thin stainless-steel sheets, especially intended for areas of use that require special hygienic-sanitary conditions, is frequently researched due to the very high costs and the special conditions required [2]. The welding of thinner stainless steel thin sheets is complicated. Excess of the heat may lead to burnout. Less heat causes insufficient weld penetration and generates brittle joints [3]. The welding procedure selected plays a crucial role in the process's success. The behaviour of spot-welded stainless steel structures can be with poor performance of the joints through the loss of structural integrity [4]. The technologies used for these situations used electron or laser beams, which are very expensive. In order to streamline the joint technologies, the research is focused on the concentration of the necessary energy on the joint area, with the development of the quantities of heat necessary to melt the components in the connection area in a short time.

This experimental research is intended to replace unconventional expensive welding technologies, increasing the performance of the WIG procedure, based on concentration of the energy.

## 2 RESEARCH METHOD

Before drawing up the experimental program, the properties of the material to be joined were analyzed very carefully - thin sheets of stainless steel with the brand 1.4301 (304). According to the specifications of EN 10088-2: 2005, this steel has the following chemical composition: C - 0.0 - 0.07%; Cr - 17.50 -

19.50%; Mn - 0.0 - 2.00%; Si - 0.0 - 1.00%; Ni - 8.00 - 10.50%; N - 0.0 - 0.11%; P - 0.0 - 0.05%; S - 0.0 - 0.02%. This category of stainless-steel sheets 1.4301 (304), [5] is frequently used in the manufacture of articles for use in food practice, sanitary articles, respectively in the pharmaceutical and food manufacturing industry. It is mandatory in these areas that the exposed surfaces be very low roughness, corrosion resistant and easily sanitized. From the manufacture, the sheets have an excellent resistance to corrosion in many environments and when in contact with various corrosive materials. Crevice pitting and corrosion can occur in chloride-containing environments. Stress corrosion cracking can occur at over 60 °C. The material has good oxidation resistance in intermittent service up to 870 °C and in continuous service up to 925 °C. However, continuous use at 425-860 °C is not recommended if corrosion resistance in water is required. At thermal stresses above 500 °C the material may have a sensitivity to corrosion, but not to aqueous. During sheet metal processing, care must be taken with the metallic materials they come in contact with, as there is a danger of cross-contamination of the stainless steel by slightly corroded metals which may discolor the surface of the manufactured product. This type of steel hardens easily. Manufacturing methods involving cold processing may require an intermediate annealing step to attenuate the hardening of the work and to avoid breaking or cracking. Upon completion of manufacturing, a complete annealing operation must be used to reduce internal stresses and optimize corrosion resistance. In general, the workability of the sheets is quite good. It has a low thermal conductivity. 304 stainless steel cannot be hardened by heat treatment. It was sometimes recommended that the parts be subjected to an

annealing heat treatment, with heating to 1010-1120 °C, followed by rapid cooling, interphase or at the end of processing. The fusion welding performance for this type of stainless steel is excellent. Heavy welded sections may require annealing after welding [5].

The selection of the welding process is an important step in the design of welding technology for a particular welded joint in particular or for the entire welded construction in general, with profound technical, economic, quality, safety, etc. implications [3].

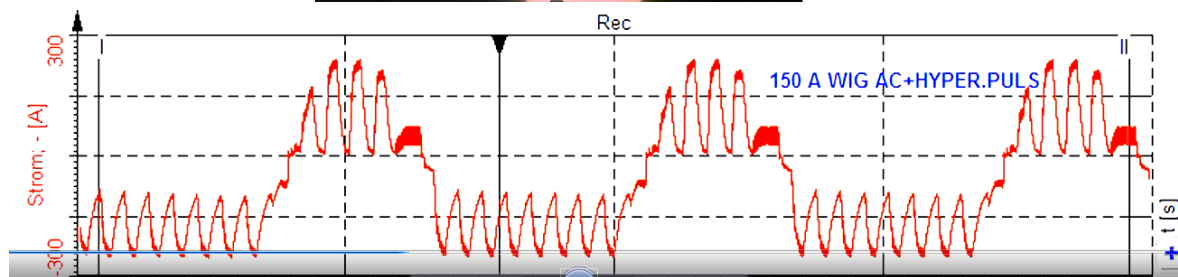
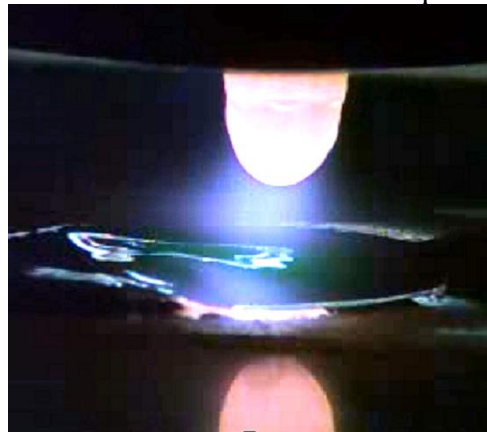
In general, the choice of welding process is made in two stages:

- selection of welding processes that allow solving technological problems from a technical point of view;
- the choice between the welding procedures previously established of the one that determines the maximum economic efficiency [4].

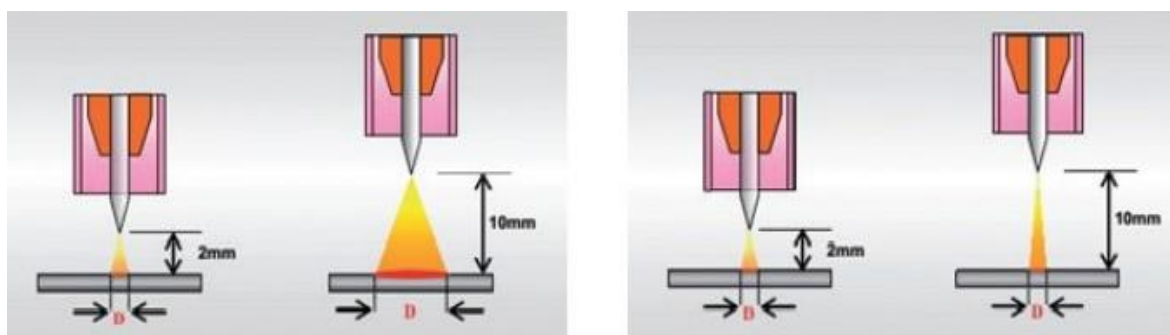
Considering these particularities, it was chosen as a variant of spot welding by the WIG process, derived from „Wolfram Inert Gas”, the electrode is infusible, being made of tungsten, and the shielding gas is chemically inert. The advantages of applying this procedure are [6]:

- the best quality of the welded joint, with the highest degree of purity and without defects in the joint;
- high universality, welding practically all metallic materials, any shape and size of seam;
- absence of slag on the seam; absence of splashes when welding;
- the possibility of welding thin sheets (less than 1 mm to 0.5 mm).

In order to achieve the pointing of the sheet metal components, the pulsed WIG variant was chosen, which differs from the classical welding by the variation of the welding current between two extreme values called pulse current and base current, with a certain frequency [7].



**Figure 1** – Images during the procedure WIG AC + HIPER:PULS, 150A [9]



**Figure 2** – Comparative welding images between standard WIG DC (left) and WIG DC using the Dynamic Arc (right) function [8]

Choosing a high-performance welding equipment helps a lot both to improve the quality of the welding

operation and in the correct learning process of the WIG welding process. There is equipment on the

market that offers a multitude of special functions that allow a significant improvement in quality and productivity. Figure 2 shows comparative welding images between standard WIG DC, (left) and WIG DC using the Dynamic Arc function. The latter allows the welding current to increase when the arc voltage decreases and the welding current to decrease when the arc voltage increases, respectively. It allows welding using a very short arc, because when the electrode is very close to the base material the welding current increases, avoiding the soldering of the electrode and the contamination of the welding bead by pushing the bath [8]. Thus, the melting of the material and the formation of the metal bath take place during the impulse time, while in the base time the stable combustion of the electric arc is maintained, achieving a cooling with the partial solidification of the molten bath. At the same average welding current, the seam penetration increases compared to conventional WIG welding, and the linear energy is lower, which leads to a reduction in welding stresses and strains [7].

### 3. EXPERIMENTAL RESEARCH

The experimental study was performed using a REHM HYPER.PULS welding equipment, used for the temporary joining (weld points) of 2 types of steel sheet 1.4301 (304), being selected for in-depth analysis:

- 4 sample with welded sheets (weld points), corner, 1 mm thick steel, 1.4301(304), (A1-A4);
- 2 samples, perforated sheet, 1.5 mm thick, marked with B1 and B2, (Figure 3);



Figure 3. – Temporarily welded sheets (weld points), corner, 1 mm thick, steel 1.4301(304), (A1-A4)

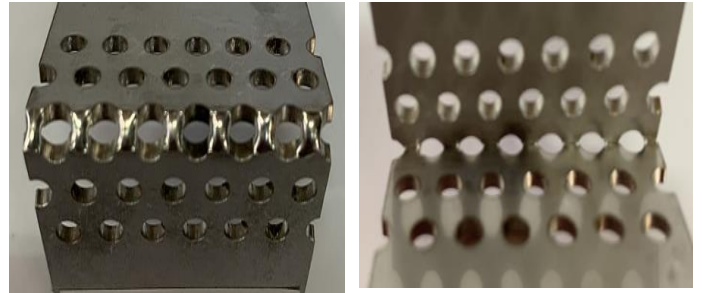


Figure 4. – Perforated sheets, temporarily welded (points), corner, 1.5 mm thick, steel 1.4301(304), (B1, B2)

The welding parameters applied are listed in Table 1. The meanings of the abbreviations in the table are: Tk<sub>bm</sub> = Base material thickness [mm]; T<sub>p</sub> = Preparation time [s]; E<sub>p</sub> = Priming energy (ICS) [%]; I<sub>s</sub> = Starting current [A]; T<sub>cr</sub> = Current rise time [s]; I<sub>1</sub> = Welding current 1 [A]; I<sub>2</sub> = Welding current 2 [A]; T<sub>cd</sub> = Current decrease time [s]; I<sub>fc</sub> = Final crater current [A]; T<sub>pg</sub> = Post-gas time [s]; f = Pulse frequency [Hz]; T<sub>s</sub> = Scoring time [s]. Table 2 continues the presentation of the parameters in which the welded joints were made, with the determination of the amount of heat introduced, determined with the relation:

$$Q = U \times I \times t, [Ws] \quad (1)$$

Table 1. Spot welding parameters

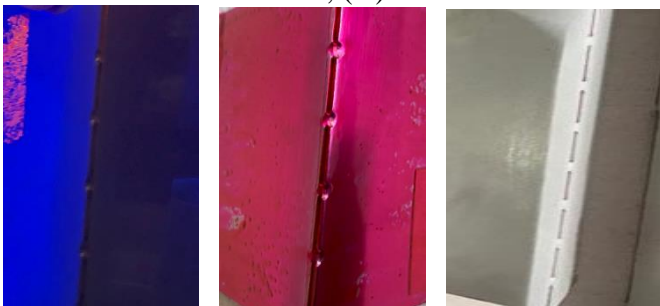
No. Sample	Tk <sub>bm</sub> [mm]	T <sub>p</sub> [s]	E <sub>p</sub> (ICS) [%]	I <sub>s</sub> [A]	T <sub>cr</sub> [s]	I <sub>1</sub> [A]	I <sub>2</sub> [A]	T <sub>cd</sub> [s]	I <sub>fc</sub> [A]	T <sub>pg</sub> [s]	f [Hz]	T <sub>s</sub> [s]
A.1	1,0	0,4	50	90	0,0	180	160	0,0	36	5	14.000	0,08
A.2	1,0	0,2	40	22	0,0	45	-	0,0	9	5	-	0,95
A.3	1,0	0,2	-	30	0,0	55	-	0,0	10	5	-	0,90
A.4	1,0	0,2	-	40	0,0	60	-	0,0	10	5	-	0,80
B.1	1,5	0,4	30	10	0,0	160	100	0,0	10	10	14.000	0,04
B.2	1,5	0,2	40	30	0,1	60	-	0,0	12	5	-	0,50

Table 2. The amount of heat introduced during the spot welding

Sample No.	Arc voltage [V]	Spot welding time [s]	Arc power [W]	Heat introduced [Ws]
A.1	13,8	0,08	2.346	187,68
A.2	10,5	0,95	472,5	448,87
A.3	8,2	0,90	451	405,90
A.4	9,0	0,80	540	432
B.1	10,5	0,04	1.365	54,6
B.2	9,5	0,50	570	285

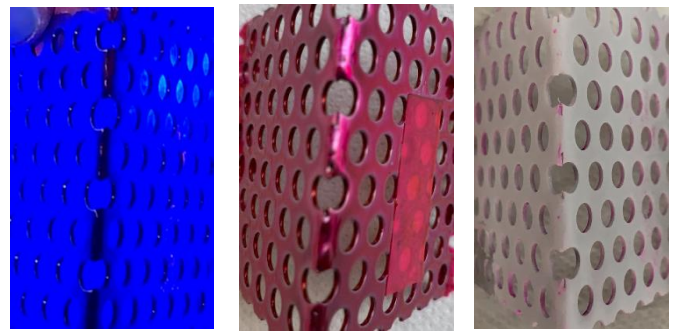
Table 2 shows the possibility of determining the optimal parameters for achieving a joint, in quality conditions, at the level of requirements and with the lowest possible costs. In order to verify the quality of the welded joints, the samples were subjected to several control and evaluation variants. After careful visual examination, the samples were examined using penetrating liquids. This process is generally applied for the detection of fine imperfections, which have openings to the surface, such as: cracks, overlaps, wrinkles, pores and possible melting defects. The recommendations contained in SR EN ISO 3452 were observed, as well as the other rules in force regarding the operational procedure, related to the examination with penetrating liquids. The investigations were carried out in compliance with the specific procedure developed by ISIM-LIEA Timisoara. Thus, the examination by spraying with fluorescent penetrating liquid was performed, then the visualization of the defects was done with a UV lamp [9].

Also, a visualization was performed following the use of ionized X-ray radiation, a method of non-destructive examination / non-destructive testing already established. The specific procedure was followed by the radiographic examination, with penetrating X-rays, elaborated by LIEA - ISIM Timisoara. The procedure regulates the technical conditions for radiographic examination of welded materials, parts and joints using type X ionizing radiation [9]. The procedure establishes the elements and the technical conditions for highlighting and appreciating the discontinuities opened at the surface by the method with penetrating liquids. Figure 5 shows the images of the examined samples, with the complex process of using penetrating liquids, for the case of joining sheets with a thickness of 1 mm, (A).



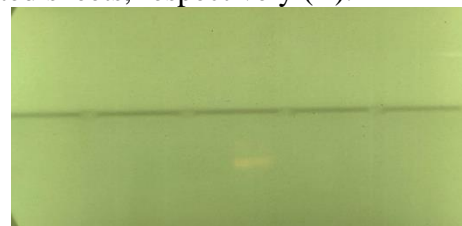
**Figure 5.** – Images of 1 mm thick sheet samples (A) under the examination procedure with penetrating liquids

Figure 6 shows the images of the samples examined by the same procedure for the case of joining perforated sheets with a thickness of 1,5 mm, (B).

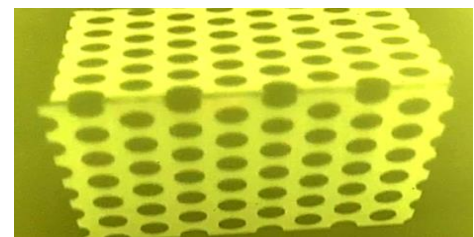


**Figure 6.** – Images of perforated sheet samples (B) under the penetrating examination procedure

The results of the examination were assessed, considering the acceptance / rejection criteria according to EN ISO 23277, as well as SR EN ISO 5817. Figures 6 and 7 are images of the 1 mm thick sheet samples (A), under the examination procedure with penetrating X-rays, and of the 1.5 mm thick perforated sheets, respectively (B).



**Figure 7.** – Images of sheet metal samples 1 mm thick (A) under the examination procedure with penetrating radiation X



**Figure 8.** – Images of perforated sheet metal samples (B) under the penetrating radiation examination procedure X

All samples were subjected to radiographic examination, in accordance with SR EN ISO 17636-1: 2013, Non-destructive examinations of welds. Part 1: Techniques using X-rays or film gamma (X-rays) to examine and certify the quality of products, on the basis of SR EN 1330-1: 2015, finding that they are within accessible quality limits in accordance with the quality standards in force, without significant surface defects.

#### 4. CONCLUSIONS

The experimental study highlighted the importance of increasing the performance of temporary jointing of thin stainless-steel sheets, by concentrating energy as close as possible to the right joint, without too much influence the neighboring areas, the thermally influenced area being very low,

for each point in part. As noted in the tables with the applied parameters (1 and 2), there is a substantial reduction in costs, through lower energy losses and shorter operating time. There is also a precision of the joint, in the conditions of a safe, punctual melting, without requiring a too complicated preparation of the welding conditions and without a too high specialization of the operators. The applied method ensures a much higher economy than conventional processes. The judicious use of energy concentration during welding brings the process closer to unconventional, newer and modern technologies.

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