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COMPARATIVE ANALYSIS OF WELDED AND ADHESIVE JOINTS STRENGTH MADE OF ACID-RESISTANT STAINLESS STEEL SHEETS

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ABSTRACT
The article presents the selected results of strength tests on the effectiveness of bonding high-alloy steel 1.4310. Sheet steel is one of the materials that are difficult to activate energy. Effective joining of it is difficult, requires selection of the appropriate bonding technology. The paper focuses on the comparative tests of shear strength of one-single lap welded and bonded joints. The welding process was performed on 3 groups of samples TIG welding and argon, where the variable value of the welding process was current: 60A, 70A, 80A. The adhesion process was performed in 6 groups of samples which differed in the method of surface preparation and the type of the adhesive. Adhesive joints were made by using adhesive of epoxy resin and a hardener: Epidian 61/TFF at a mass ratio of 100:22 and Epidian 61/IDA at a mass ratio of 100:40. As a way of surface preparation applied 3 different, but simplified and environmentally friendly methods of surface preparation: degreasing with using cleaner Loctite 7061, abrasive machining with P320 and degreasing and grinding with abrasive T800 and degreasing were used. Make joints and curing the adhesive joints were carried out at ambient temperature. Analyzed the joints were tested destructive – which set out the shear strength, in accordance with DIN EN 1465 on the testing machine Zwick / Roell Z150. Based on the results of the research it was found that better results were obtained for the maximum welded joints, but this result was similar to the maximum value of the strength of the adhesive bond.

Keywords: adhesive joints, welded joints, strength, acid resistant steel

INTRODUCTION

Acid resistant steel is a material with interesting properties. They are used in many industries, especially in: chemical, food, aerospace, machine-building, refinery – petrochemical (parts of: pumps, valves, bolts, automatics) as well as in the construction of dairy equipment and brewing (fittings, pumps, valves), architectural (facades lining, window frames, interior design). Wide spectrum use of this material makes the assembly process of elements made of acid-re-

sistant steel sheets, applies often to use permanent joints. Obtaining these joints is possible in a wide range of process, for example: bonding and welding [4,6,9].

Welding is the process of melting the edges of the joined elements, mixing the formed adhesive and their melts and lead to recrystallization of molten sites. Due to the development of welding technology, it is possible to join any kind of steel, by a suitable method (TIG, MIG, MAG, electron beam welding, laser welding) [4,9]. Welding processes are generally carried out by using concentrated heat source, causing local heating to a temperature depends on the properties of the base material and the type of used process. The temperature must be higher than the melting point of metal [10,16].

Adhesive joints, in contrast to welded joints, are lighter and they resist to corrosion. They are characterized by greater strength to vibration and bending [5]. However, acid-resistant stainless steel belongs to a group of resisting adhesive materials. The effectiveness of adhesive depends mainly on the choice of appropriate adhesive and application of the relevant surface preparation technologies [8,14,15]. Surface preparation for bonding various materials is different [2,12]. For carbon steel is usually per-form purification, mechanical surface development and degreasing. For alloy steels, to which is classified as acid-resistant stainless steel, to obtain a good quality bonding normally need a proper chemical processing, rinsing and drying. For alloy steels, to which is classified as stainless steel, to obtain a good quality connection normally need a proper chemical processing, rinsing and drying. However, these are usually technology with a high level of environmental damage.

The paper presents a comparative analysis of welded and adhesive joints strength made of acid-resistant stainless steel sheets 1.4310. The aim of the study is to determine and compare the effect of welding parameters (current intensity) and adhesive (surface preparation, the type of used adhesive) on the share strength.

METHODOLOGY OF RESEARCH

Connected material

Experimental studies used samples made of 1.4310 sheet. It is an acid-resistant stainless steel, spring-loaded, anti-magnetic with high carbon content, good discharge properties and good toughness. It is a stainless steel, steel, spring-loaded, non-magnetic with high carbon content, good discharge properties and good tough. Mechanical and physical properties and chemical composition of steel 1.4310 were shows in tables 1 and 2.

Due to properties shown in Table 1, acid-resistant stainless steel is used for springs, spring washers, rope, draw bar, fasteners, aircraft parts and other components used in the chemical and food industry, such as parts of pumps, acid tanks or springs working at high temperature [7].

Welded joints

For this study were prepared single-lap welded joints. Dimensions are shown in Fig. 1 and Table 3.

Welded connections were made by using TIG welding method. Three kinds of currents intensity have been applied: 60A, 70A, 80A. Connections were made by using argon arc machine Fantasy Digital Welder, argon-shielded arc with use of solid welding wire ER 308LSi, at ambient temperature 19°C, at a humidity of 21%. Welded joints made of acid-resistant stainless steel 1.4310 sheet, were subjected to a destructive test on testing machine Zwick/Roell Z150, according

Table 1. Mechanical and physical properties of steel 1.4310 according to EN 10088–1 [11]

Tensile strength, R_m	Yield strength, R_e	Elongation, A	Shear moduls, E	Thermal capacity, c_p	Thermal conductivity, λ	Hardness
500–700 MPa	≥195 MPa	>40 %	200 GPa	500 $J \cdot kg^{-1} \cdot K^{-1}$	15 $W \cdot m^{-1} \cdot K^{-1}$	<230 HB

Table 2. Chemical composition of steel 1.4310 according to EN 10088–1 [11]

Sort of steel	Chemical composition [%]								
	C	Mn	Si	P	S	Cr	Ni	Mo	N
1.4310	0.05–0.15	0–0.2	0–2.0	0–0.045	0–0.015	16–19	6–9.5	0–0.8	0–0.11

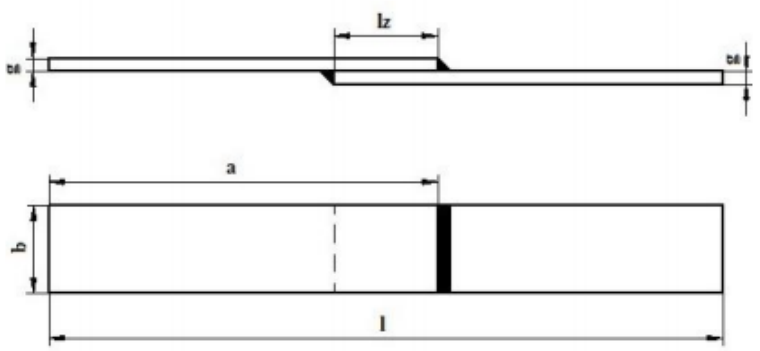

Fig. 1. The welded joint of 1.4310 sheet

Table 3. The welded joints dimension

Designation of dimension	a [mm]	b [mm]	g [mm]	l [mm]	l_z [mm]
Measurement	100	20	8	180	20

to Norm DIN EN 1465 [3], at the test speed of 5 mm/min. These tests were to determine the shear strength of welded joints.

Adhesive joints

For this study single-lap adhesive joints were prepared. Dimensions are shown in Figure 2 and Table 4.

The length of the overlap was calculated by the formula to limit length of overlap as set out in the research work [1]. The adopted overlapping length of adhesive joint was 20 mm.

Samples surface of acid resistant stainless steel sheet to the adhesion process was prepared using three methods:

1. degreasing by using Loctite 7061,
2. mechanical processing with P320 abrasive tool, and cleaning with degreasing Loctite 7061,
3. mechanical processing with T800 abrasive tool and cleaning with Loctite 7061 degreasing agent,

Degreasing process consisted of 3-fold degreaser applied by spraying on the surfaces to be joined and wipe them with a paper towel. After the last step of imposing a measure, the degreaser was allowed to air dry and evaporates. Time from degreasing until the adhesive application was 10 minutes.

Adhesive joints were made by using two adhesive compositions consisting of epoxy resin Epidian 61 and hardener: TFF and IDA in differ-

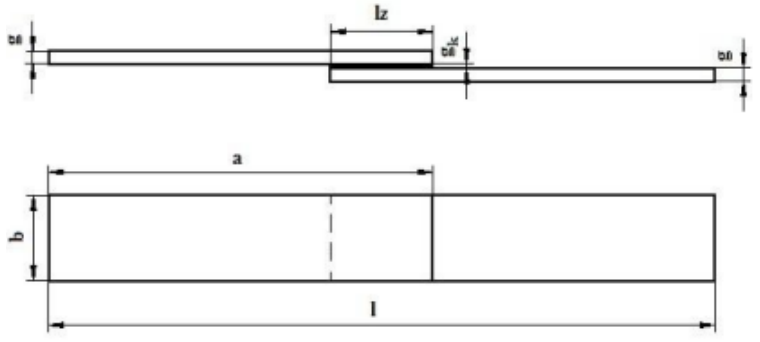

Fig. 2. The bonded joint of 1.4310 sheet

Table 4. The adhesive joints dimension

Designation of dimension	a [mm]	b [mm]	g [mm]	l [mm]	l_z [mm]	g_k [mm]
Measurement	100	20	8	180	20	0.1

ent weight ratios: for TFF hardener ratio of resin to hardener was 100:22, for the IDA hardener ratio was 100:40. To measure out components weight-the TP type 2/1 certified ISO9001 were used for the accuracy of the applicant 0.1 g. The adhesive compositions were prepared immediately prior to the bonding process and were manually applied to one surface to be joined, after which the sample was determined with the use of retaining device [13]. Adhesive joints were made in laboratory conditions at 24° C and 23% relative humidity, and were cured in a single stage time of 10 days under a load of 0.5 kg. After this time, the adhesive joints of stainless steel sheet was tested for destructive testing machine, Zwick / Roell Z150 according to DIN EN 1465 [3], wherein the test speed of 5 mm/min. These tests were to determine the shear strength of adhesive joints.

TEST RESULTS

The strength of welded joints

Figure 3 shows the effect of current intensity during the TIG welding on the shear strength of the welds acid-resistant steel sheet 1.4310.

Analyzing the results of tests summarized in Fig. 3, it can be seen that the strength properties increases with increasing current intensity. The highest strength was achieved with the application of the highest current intensity – 80A and it was 14.9MPa. Slightly lower value of the strength achieved for 70A of 12.1MPa, while the lowest intensity 60A – 7.8MPa.

The strength of adhesive joints

Figure 4 shows the strengths of the adhesive joints of 1.4310 stainless steel sheet made with Epidian 61/TFF/100:22 and Epidian 61/IDA/100:40 adhesive.

Based on the results of the shear strength test of the analyzed adhesive joints of 1.4310 stainless steel sheets made using the Epidian 61/TFF/100:22 and Epidian 61/IDA/100:40 adhesive mixtures, taking into account various surface preparation methods (Fig. 4), the method of preparing the surface of the bonded elements for both adhesives is not the same. For connections made with Epidian 61/TFF/100:22, the highest strength was obtained for Loctite 7061 degreased samples and it was 8.6 MPa. The lowest strength was achieved for the samples subjected to abrasive machining T800 and degreased, which is 81% of the highest strength values.

For connections made with Epidian 61/IDA/100:40, the highest strength was achieved for the samples whose surface was prepared with mechanical treatment with a P320 abrasive blast and degreased tool and it is 11.4 MPa. On the other hand, the lowest strength was achieved for Loctite 7061 degreased samples, which represents 46% of the highest strength value. The lowest strength was achieved for the samples degreased Loctite 7061, accounting for 46% of the highest strength values.

Comparative analysis of shear strength of welded and adhesive joints

Figure 5 presents a comparison of the shear strengths of welded and adhesive joints of 1.4310 stainless steel sheet.

Comparing the obtained results shown in the graph (Fig. 5) of the strength of adhesive joints and welded shear-resistant 1.4310 stainless steel sheet, it can be seen that:

1. the highest strength was for welded joints with current 80A – 14.9 MPa, but for all welds the

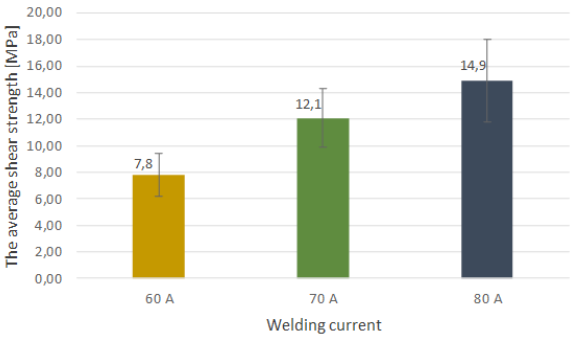

Fig. 3. The welded joints on shear strength of 1.4310 acid-resistant steel sheets

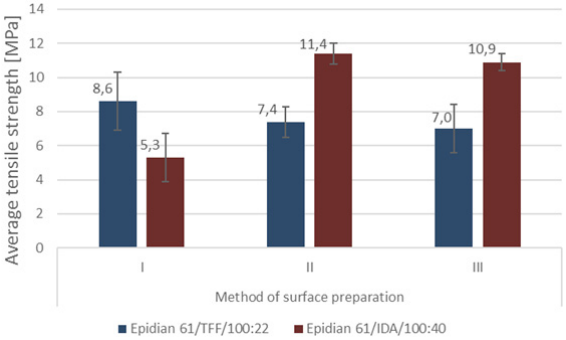

Fig. 4. The bonded joints shear tensile strength of 1.4310 sheets

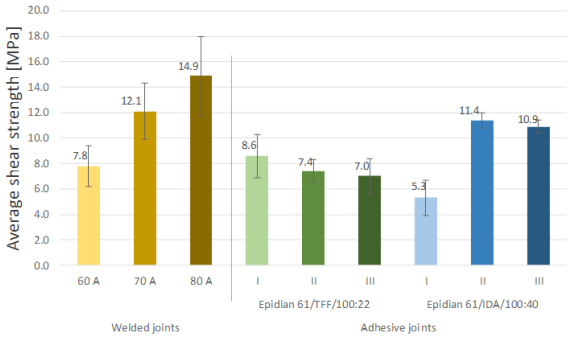

Fig. 5. Comparison of shear strength of welded and bonded joints of 1.4310 acid-resistant steel sheets

standard deviation from the average strength was significantly higher than for adhesive joints (Fig. 5),

2. for I method of surface preparation (degreasing with Loctite 7061), higher strength was obtained for adhesive joints made using Epidian 61/TFF/100:20 adhesive and amounted to 8.6 MPa,
3. for the II method of surface preparation (mechanical abrasive tool P320 + degreasing with Loctite 7061) higher strength was obtained for joints made using the adhesive composition: Epidian 61/IDA/100:40 (11.4 MPa),
4. for the III surface preparation method (mechanical treatment with T800 abrasive and degreasing with Loctite 7061), more than twice the strength (10.9 MPa) characterized the joints made with Epidian 61/IDA/100:40 adhesive,
5. the highest repeatability of the results was achieved by adhesive joints for II and III method of surface preparation for Epidian 61/IDA/100:40 compositions,
6. welded joints current of 60A have a lower shear strength than adhesive bonds made using the adhesive Epidian 61/TFF/100:20 sheets whose surface was prepared I method (Loctite 7061 degreasing agent),
7. welded joints current of 60A have a lower shear strength than adhesive joints made with Epidian 61/IDA/100:40 sheets which the surfaces were prepared with II and III method.

SUMMARY AND CONCLUSIONS

Welded and adhesive joints, which were the subject of experimental studies are used throughout the world. Welded joints are considered to be inseparable joints and are widely used in the assembly field. The quality of the connection depends on the experience of the welder. Adhesive bonds are also categorized into permanent joints. The bonding technique is fast evolving and continues to improve, making the adhesive joints highly strength. Surface phenomena play a very important role, which depends on several factors: operating, material, construction and technology.

The research that was carried out in the work uses TIG method of welding in argon shielding. This method was chosen because it is described as the most advantageous in the case of welding stainless steel sheets which were used in the research. During the performance of welded joints, it has been observed that:

welded samples at 60A current were difficult to weld because the current was too low. Welding wire stuck to the joints, and the electric arc dangled very close to the material, which required high precision of joints,

- welds at 70A current welded more easily than at 60A, the arc worked properly, and the welding wire used did not glue to the joined elements and the sample was not melted,
- Welding samples at 80A current were more difficult to weld than at 70A. The material of the welding wire did not stick to the metal sheets, but due to the high current they melted due to the high temperature, however, the highest strength was obtained for these samples (Fig. 5).

Two types of Epidian 61/TFF/100:22 and Epidian 61/IDA/100:40 epoxy adhesives were used for adhesive joints. Both of them were used to perform the three groups of samples which differed from each other method of surface preparation:

- degreasing using Loctite 7061,
- mechanical abrasive with sandpaper P320 and degreasing with Loctite 7061,
- machining abrasive with sandpaper T800 and degreasing Loctite 7061.

A method of surface preparation, and the type of adhesive were variable factors in the study, while other conditions remained unchanged.

On the basis of the results of strength tests and analysis you can draw the following conclusions:

- the strength of welded joints increases with the increase of current,
- the highest strength characterized welding joints at the current of 80A, the technological reach was more difficult to weld than at 70A,

- the highest strength of the adhesive joints was obtained in the case of samples prepared by the II method of surface preparation and jointed with Epidian 61/IDA/100:40,
- higher reproducibility of results was obtained with adhesive joints.

In conclusion, it can be seen that a higher maximal result was obtained for welded joints. This result did not differ significantly from the maximum strength of the adhesive joint. The strength of the adhesive joint is influenced by, inter alia, appropriate selection of adhesive and method of surface preparation. Implementation of welded joints requires both appropriate skills and capabilities of the person performing the connections, as well as specialized tooling, so the preferred method of bonding issued by the epoxy adhesive composition Epidian 61/IDA/100:40, provided the appropriate surface preparation of connected elements. Moreover, the use of this type of adhesive joints, allows for shear strength comparable to the strength of welds performed with a lower current intensity (70A). It is anticipated that the comparative studies of welded and adhesive joints will be completed in the longer term of seasoning and higher temperatures.

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