The International Journal of Engineering and Science (IJES)
|| Volume || 11 || Issue || 5 || Series I || Pages || PP 01-05 || 2022 ||
ISSN (e): 2319-1813 ISSN (p): 20-24-1805

Use of laser welding in welding thin-walled sheet metal parts

[1]Jan Viňaš,[1]Janette Brezinova, [1]Henrich Sailer,
[1]*Technical university in Kosice, Faculty of mechanical engineering, Department of Technology, Materials and Computer Aided Manufacturing, Slovakia*

--***ABSTRACT***--
Implementation of lightweight low-ductility materials such as ultra-high strength steels, has become urgently needed for automotive manufacturers to improve the competitiveness of their products. Automotive industry is focusing on lightweight and high strength materials. The aim of the research was to evaluate the influence of the parameters of steel laser welding on the qualitative indicators of butt welds. A tensile test and yeld strength test were performed on selected samples, where the strength of welded joints was determined.
KEYWORDS;- Laser; Welding; Dual phase Steel, Heat treatment, Transformation-inducted plasticity steel,

---

Date of Submission: 14-05-2022 Date of Acceptance: 27-05-2022

I. INTRODUCTION

Laser welding technology is used in various sectors. Thermal cycle at Laser welding is usually faster than they involve conventional arc technologies lead to small weld widths and heat affected zones. The use of laser technology began in 20th century. In many studies, their first results were not satisfactory. The first generation of CO2 lasers has succeeded basic material in jobs only to be heated, however, do not melt. In 1971 it was for the first time the "keyhole" (KD) effect achieved. Nowadays, there are laser technologies widely used in combination with modern computer technology. Mainly in areas mechanical engineering, energy, electrical engineering, medicine and the army. In mechanical engineering, they record laser technologies in conjunction with robotization enabling 5 dimensional movement the greatest development mainly in the automotive industry, they are most often used for engraving, heat treatment of materials (hardening), cutting and especially welding. Nowadays car manufacturers such as Audi, Mercedes, BMW, Volvo, Volkswagen, and Skoda use laser technology for reasons of increase: productivity, product quality and competitiveness [1]. Weight reduction of automobiles is one of the effective measures for decreasing gas consumption and minimizing environmental pollution on the premise that safety provisions are guaranteed. It was estimated that 10% of weight reduction generally may bring about 5% less of gas consumption [2]. Therefore, these years light metal materials such as Al alloys and Mg alloys have been increasingly used in automobile industry. But the high cost of manufacturing all light metal car body has greatly limited the usage expansion. During the past years, ultra-high strength steels (UHSS) such as transformation induced plasticity (TRIP) steels and dual phase (DP) steels were increasingly applied in automobile industry due to their good combination of high strength and formability. The excellent mechanical properties of TRIP steel mainly contribute to the ferrite matrix, for ductility, bainite, for strength, and retained austenite, for uniform elongation produced by martensite transformation from austenite when subjected to external tensile stress [3-6]. Paper presents the results of research into two grades of steel that are currently used in the production of body parts of middle class passenger cars.

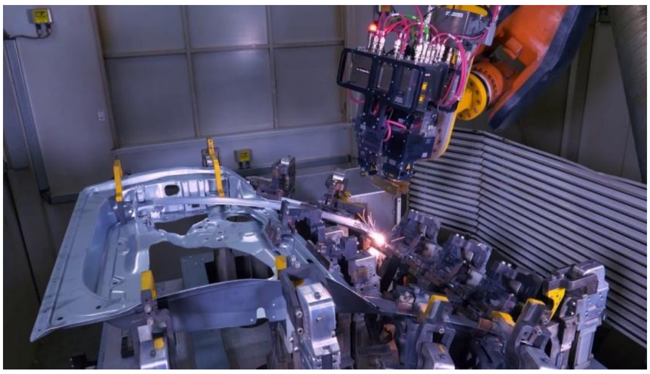

Figure 1. Remote laser welding of doors in series production of a major car manufacturer

II. MATERIALS AND METHODS

Within the experiment, selected types of steels that are used in the production of bodies and their components in the automotive industry were evaluated. Samples made of double-sided galvanized sheet steel HSLA 0.81 mm thick were marked as A. Samples marked B were made of double-sided hot-dip galvanized steel sheet DP 600 with a thickness of 0.8 mm. The chemical composition of the steels used and their mechanical properties are presented in Tables 1. and Table 2.

A HSLA	**C**	**Mn**	**Si**	**P**	**S**	**Al**	**Cu**	**Cr**
	0.005	0.409	0.128	0.037	<0.002	0.034	0.015	0.031
	Mo	**Ni**	**V**	**Ti**	**Nb**	**Co**	**W**	**Fe**
	0.008	0.006	0.006	0.033	0.035	0.021	0.038	Res.
B DP600	**C**	**Mn**	**Si**	**P**	**S**	**Al**	**Cu**	**Cr**
	0.111	1.963	0.279	0.026	<0.002	0.031	0.019	0.206
	Mo	**Ni**	**V**	**Ti**	**Nb**	**Co**	**W**	**Fe**
	<0.002	<0.002	0.012	<0.002	0.020	0.017	0.005	Res.

Table 1. Chemical composition of welded steel sheets (wt.%)

Steel	Yield strength [MPa]	Limit of strength [MPa]	Elongation A_5 [%]
A - HSLA	240 - 330	340 - 450	32
B - DP600	300 - 470	580 - 670	26

Table 2. Mechanical properties of the evaluated sheets specified by the manufacturer

Welding

Laser welding was performed using a CO2 laser AF8P with a max. with an output of 8 kW and a wavelength of 10.6 μm. Before welding, the edges of the sheets were adjusted after cutting on a CNC milling machine. The samples were welded along the entire width of the sheets (800 mm) in the PA position in accordance with STN EN ISO 6947 without a gap between the sheets [7].

Welding parameters used:

- power - P = 1700 W,
- laser mode - TEM 10 - Gauss,
- shielding gas Ar 4.8, flow rate 20 l/min,
- welding speed 2.0 m/min,
- beam focusing - on the surface of the sheet f = 0mm,
- wavelength λ = 10,6 μm.

Used methods for evaluating the quality of welded joints

The quality of laser welded joints was assessed using:

- visual inspection of welds in accordance with ISO 17637,
- tensile tests of a welded joint in the transverse direction according to EN ISO 4136,
- evaluation of microhardness of welded joints on transverse metallographic cuts according to Vickers in accordance with EN ISO 9015-2 at applied load of 981.0 Nm^{-1}. The microhardness values were evaluated in the base material, the heat-affected zone and in the weld metal.
- macroscopic and microscopic analysis using an Olympus BXFM light microscope was performed on metallographic sections according to EN ISO 17639. NITAL etchant (2% HNO_3 solution) was used for visualization of macro and microstructures [7].

III. RESULT VIEW

Analysis of the quality of welded joints by visual inspection did not show the presence of external surface defects such as pores, cracks or. overflowed root, but the difference in thicknesses between the base material and the joint was recorded, which is documented on the macrostructures. Based on the results of destructive tests for individual evaluation methods, which are presented in the summary Table 3, it can be stated that the maximum load-bearing values were shown by samples B, where the following average values YS (Yield strength) is 372 MPa and UTS (Ultimate tensile strength) is 620 MPa were measured, which is consistent with the values declared by the manufacturer. The lowest values of bearing capacity of welded joints were measured in samples A, where the average value YS is 319 MPa and the value UTS is 422 MPa were measured. During the uniaxial tensile test of samples with transverse laser welding, all evaluated samples were destroyed in the base material.

Sample	Yield strength [MPa]	Ultimate tensile strength [MPa]	Destruction
A HSLA	319	422	Basic material
B DP600	372	620	Basic material

Table 3. Average values of tensile properties of experimental steel

Macroscopic analysis of metallographic sections confirmed the results of visual inspection of welded joints. The surface of the weld metal made by the laser had a distinctive drawing with a well-readable welding direction. The structural analysis was performed by light microscopy on cross sections. The macrostructure of the welded joint of sample A after etching is documented in Figure 2. In the etched state, the width of the weld metal and the width of the heat-affected zones, are well legible. The microstructure of the base material is fine-grained with an average grain size of G7 EN ISO 643, consisting of polyhedral ferrite and perlite in a volume of max. 10%.

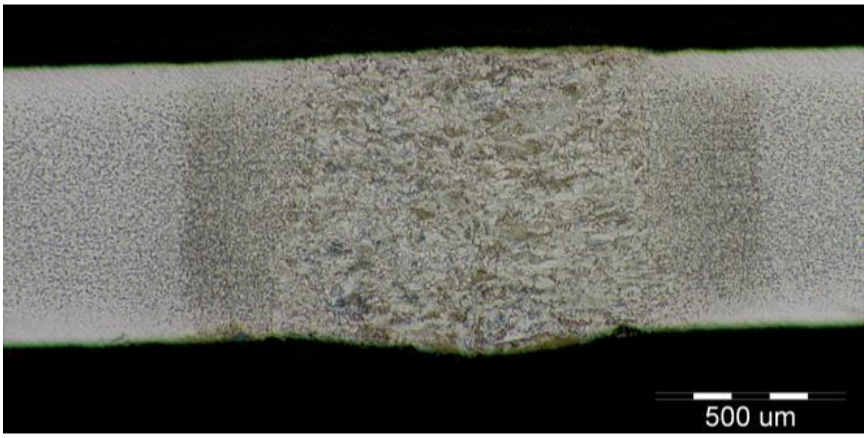

Figure 2. Macrostructure of sample A welded joint (HSLA)

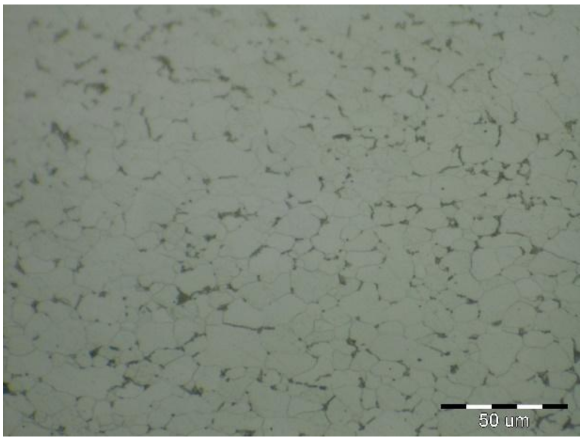

Figure 3. Basic material microstructure - ferritic-pearlitic

The macrostructure of the welded joint made by the laser of sample B is documented in Figure 10. Only a slight cant at the weld is recorded on the macrostructure. The structure of the base material of DP 600 steel (Figure 3.) is formed by a ferritic matrix in which martensite is dispersed in a volume of approx. 15%. The average grain size of the freritic matrix was G7 EN ISO 643.

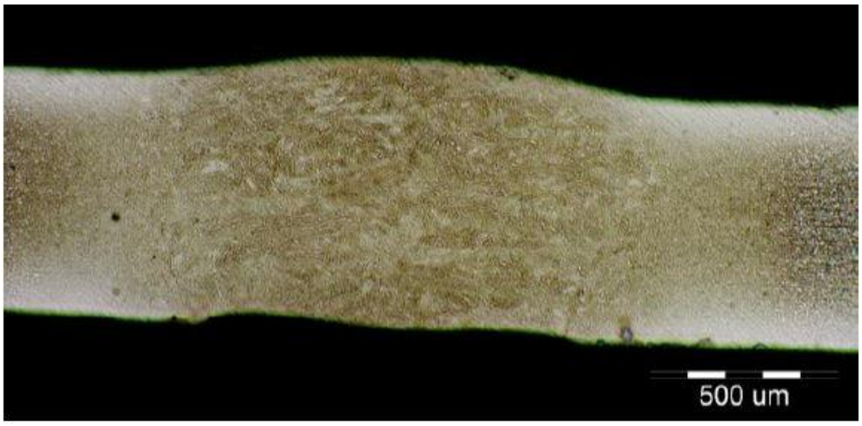

Figure 3. Macrostructure of the welded joint of sample B

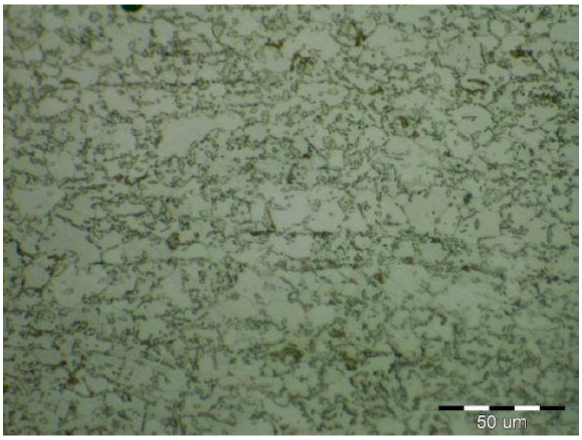

Figure 4. Two-phase microstructure of DP 600 base material

IV. CONCLUSION

In addition to the experiments, welded joints made by laser welding on two grades of steel sheets were evaluated. HSLA and DP600 steel sheets were of high quality due to their chemical composition and two-component structures. However, the issue of weldability of body sheets, especially ones with high strength, needs to be given increased attention. Multiphase weld metal structures have significant specifics during metallurgical solidification processes. Incorrect welding parameters lead to frequent errors and economic losses. This means the welding process has a detrimental influence on the steels' formability behavior. Studies show [8-10] the fusion zone has a lower decrease (45.1%) than that of the Si-alloyed steel (62.9%) at the quasi-static strain rate. The decrease is also similar for the dynamic tensile tests, although strain rate-induced increases in strength lead to higher strength–ductility balances. Al-alloyed steel fusion zone shows a multiphase microstructure, containing skeletal ferrite,

The application of laser welding as well as laser soldering in car production has an increasing tendency. Developments in the construction of laser welders, reducing the economic complexity of this welding process and high quality welded joints are the main advantages for applications in automotive production. On the other hand, these progressive, high-speed welding methods require thorough parameter optimization, especially for difficult-to-weld materials. It is necessary to apply precise preparations that guarantee the correct position of narrow welds, which is a common problem in practice. Laser welding is a suitable way of welding body sheets of various material combinations such as: DP and TRIP, BH (Bake Hardening) and DP, IF (Interstitial Free) and TRIP, etc. These mutual combinations of steel grades are increasingly used in the production of body parts in order to increase the passive safety of the crew and reduce the weight of cars.

ACKNOWLEDGNMENT

APVV-16-0359 The utilization of innovative technology for repair functional surfaces of mold casting dies for castings in automotive industry and KEGA 046TUKE-4/2022 Innovation of the educational process by implementing adaptive hypermedia systems in the teaching of subjects in the field of coating technology and welding of materials

REFERENCE

[1]. Viňáš, J. Quality evaluation of laser welded sheets for cars body. In Mat/tech – Automotive industry, Košice, Slovakia, 25 November 2005; pp. 119–124.

[2]. Yin, H.X., et al. Influence of original microstructure on the transformation behavior and mechanical properties of ultra-high-strength TRIP-aided steel. International Journal of Minerals, Metallurgy and Materials 2015, 22, 262–272, doi: 10.1007/s12613-015-1070-6.

[3]. Wang, W.Q.; Dong, S. Ch.; Jiang, F.; Cao, M. Effects of Ar and He on Microstructures and Properties of Laser Welded 800MPa TRIP Steel. In International Conference on Materials Applications and Engineering (ICMAE) Location: Qingdao, PEOPLES R CHINA, 25-27 August 2017; pp. 1–6, doi: 10.1051/matecconf/201814203004.

[4]. Viňáš, J.; Ábel, M. Analysis of Laser Welds on Automotive Steel Sheets. Materials Science Forum 2015, 818, 239–242, doi: https://doi.org/10.4028/www.scientific.net/MSF.818.239.

[5]. Viňáš, J.; Brezinová, J.; Brezina, J.; Investigation of joining zinc-coated steel sheets by laser welding for automotive industry. In Fundamental and applied problems of modern technologies. Eds. Ternopil: Ivan Puluj National Technical University, Ukraine, 2018; pp.33–34, ISBN 978-966-305-093-5.

[6]. Grajcar,A.; Różaňski, M.; Stano, S.; Kowalski, A.; Microstructure Characterization of Laser-Welded Nb-Microalloyed Silicon-Aluminum TRIP Steel. Journal Of Materials Engineering And Performance 2014, 23, No. 9, 3400–3406, doi: 10.1007/s11665-014-1118-1.

[7]. L. Binglin, J. Y. Richard Liew, A. L. Hoang: Engineering Structures 200 (2019), pp. 256-263.

[8]. Sahul, M.; Turňa, M.; Šugárová, J.; Sahul, M. Influence of laser welding aluminium alloy on mechanical properties of welded joints. Manufacturing technology 2013, 13, No. 4, 526–530.

[9]. Vontorová, J.; Mohyla, P.; Ševčíková, X. Influence of CMT and MIG Soldering on Zinc Layer Thickness. In METAL 2012 - Conference Proceedings, 21st International Conference on Metallurgy and Materials Brno, Czech Republic, 23-25 May 2012, pp. 1106–1112, ISBN 978-808729431-4.

[10]. Xia, M.; Tian, Z.; Zhao, L.; Zhou, Y. N. Metallurgical and Mechanical Properties of Fusion Zones of TRIP Steels in Laser Welding. ISIJ International 2008, 48, No. 4, 483–488

Jan Viňaš, et. al. "Use of laser welding in welding thin-walled sheet metal parts." *The International Journal of Engineering and Science (IJES)*, 11(5), (2022): pp. 01-05.