Applied Engineering Letters **Vol. 2, No. 1, 38-42 (2017)** **e-ISSN: 2466-4847**

METALLURGICAL ASPECTS OF WELDABILITY OF MULTIPHASE STEELS FOR AUTOMOTIVE INDUSTRY

M.Morawiec[1*], A.Grajcar[2]

[1] Politechnika Śląska, Gliwice, Poland, mateusz.morawiec@polsl.pl
[2] Politechnika Śląska, Gliwice, Poland, adam.grajcar@polsl.pl

Abstract:
This paper presents some of technical aspects of the twin-spot laser welding of multiphase steels for automotive industry. The dual beam was obtained using a special optical system that divides a laser beam. The investigation was carried out in two main areas of welds, which are fusion and heat affected zones. The results show that in case of analyzed steels the use of twin-spot laser welding leads to changes in martensite morphology compared to single spot laser welding in both zones. The defragmented morphology suggests that tempering-like processes occur during the welding. This phenomenon causes the decrease in weld hardness compared to single spot laser welding.

ARTICLE HISTORY
Received 23. February 2017.
Accepted 22. Mart 2017.
Available 30. Mart 2017.

KEYWORDS
twin-spot,
laser welding,
multiphase steel,
dual beam

1. INTRODUCTION

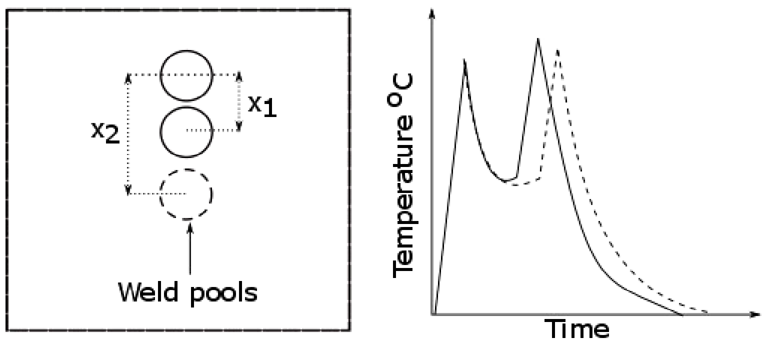
The automotive industry places very high requirements on safety and mass reduction of the car body construction. The mass reduction is related to decrease of petrol consumption that leads to lower amount of pollution created by cars. To fulfil these requirements it is necessary to use multiphase steels of high strength. These steels allow manufacturing of the thin-wall elements that decrease the total mass of car body and at the same time fulfil safety requirements [1-3]. The most important feature of the multiphase steels is their microstructure that brings a high work strengthening potential. In the case of a car body manufacturing, the joining of elements requires welding methods. One of the commonly used joining methods is laser welding. During the laser welding the initial microstructure is destroyed (melting of material and crystallization into new phases) [4-6]. This destruction leads to increase in hardness of weld compared to a base material. The difference of hardness may lead to fracture of construction elements near the weld. To decrease the difference of hardness between the base material and a weld a twin-spot laser welding method may be used [7-9]. The twin-spot laser welding allows decrease of the weld hardness by increasing the cooling time (two laser beams) [10]. There are two methods for obtaining two laser spots. In the first method two different laser heads are combined, whereas the second method uses the special optical system [7]. The twin-spot laser welding is the method used in the case of welding of aluminum and titanium alloys, coated steels and advanced high strength steels, because of its positive effect on mechanical properties of the weld [11-13].

2. EXPERIMENTAL

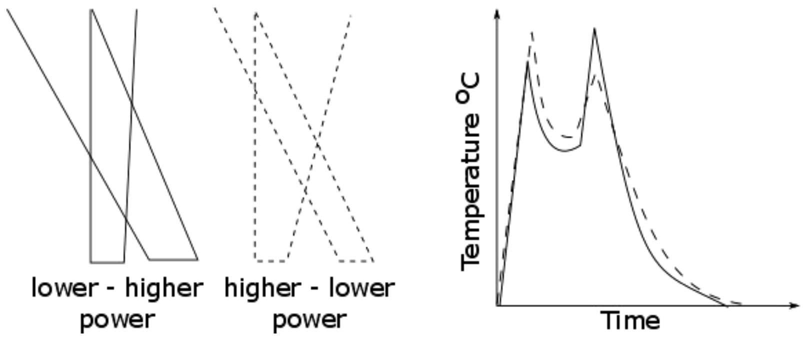
The twin-spot laser welding is characterized by complex thermal cycles that may be changed in a wide range. The most important parameters that influence the thermal cycle are: distance between laser beams, power distribution between beams, linear energy and the position of the weld pools. All the parameters that influence the thermal cycle are presented in Fig. 1. Using all these parameters it is possible to obtain various properties of welded steels. This work presents some results of the twin-spot laser welding of advanced high strength steels. The chemical composition of analyzed steels is presented in Tab. 1. The welding tests were carried

*CONTACT: Mateusz Morawiec, mateusz.morawiec@polsl.pl

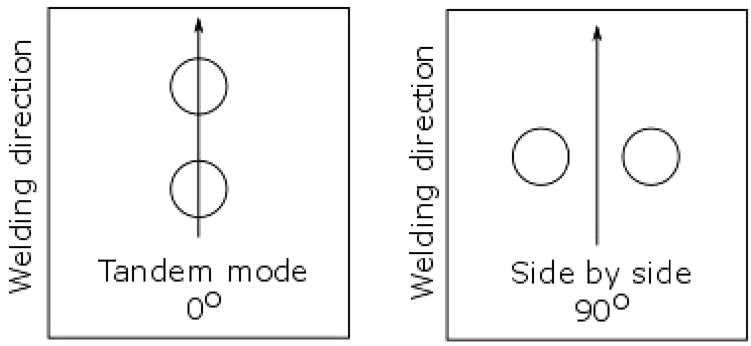
out using a robotic system for laser processing in Welding Institute in Gliwice (Poland). The laboratory satisfies the requirements of most advanced rigs and is equipped with the TruDisk 12002 – a Yb:YAG solid-state laser (Trumpf) with the maximum power of 12 kW. The two beams were obtained by a special optical system (the D70 head) that includes special optical lens which enable dividing the laser beam. The welding parameters for each steel are presented in Tab. 2.



a) Schematic presentation of how the distance between weld pools influences the thermal cycle



b) Schematic presentation of how the power distribution of beams influences the thermal cycle



c) Schematic presentation of some possible weld pools positions

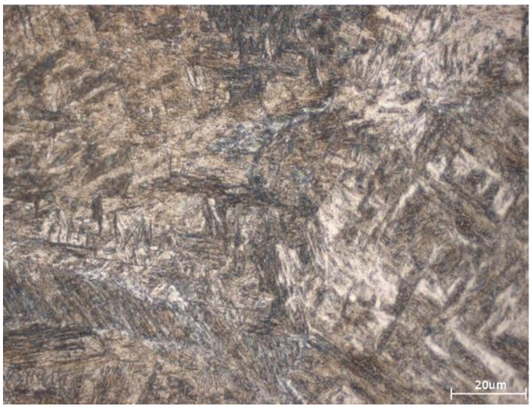
Fig. 1 Schematic presentation of parameters that influence the thermal cycles of twin-spot laser welding

Table 1. Chemical composition of analyzed steels

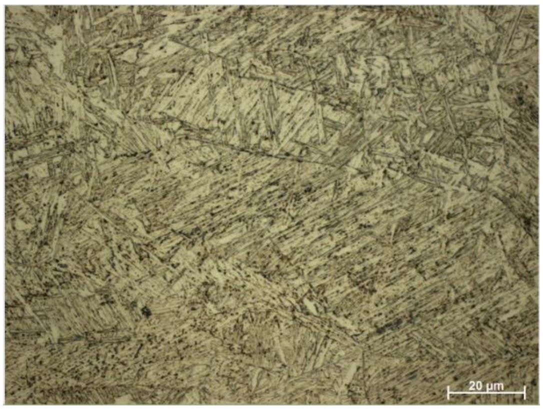
Steel	Elements	C	Mn	Si	Al	Ti	Nb	Cr	Mo	C_e
DP	[wt.%]	0.13	1.50	0.20	0.04	-	0.015	-	-	0.22
CP		0.08	1.72	0.56	0.29	0.125	0.005	0.34	0.016	0.46
TRIP		0.24	1.55	0.87	0.40	0.023	0.028	-	-	0.54

Table 2. Welding parameters of each steel sheet

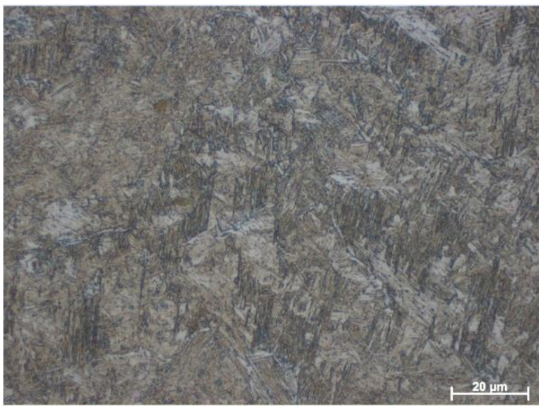
Steel	Beam power [kW]	Power distribution [%]	Linear energy [kJ/mm]
DP	6	50:50	0.048
CP	6	50:50	0.048
TRIP	6	50:50	0.048



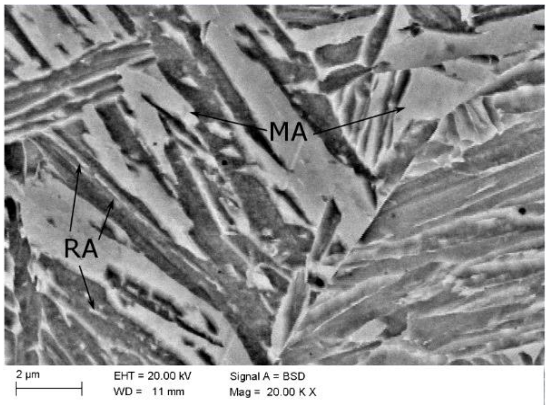
a) adual phase steel



b) complex phase steel



c) TRIP steel



d) SEM photo of CP steel

Fig. 2 Microstructure of fusion zone for investigated steels; RA - retained austenite, MA - martensitic-austenitic islands

After the laser welding the microstructure investigation was carried out. The samples were prepared by grinding on abrasive papers (80, 320, 1000 and 2500) and polishing (diamond and corundum slurry). The microstructure of specimens was revealed by etching in 3% Nital and then in aqueous solution of sodium pyrosulphate for retained austenite observation. The microstructure investigations were performed using MeF4 light microscope (Leica).

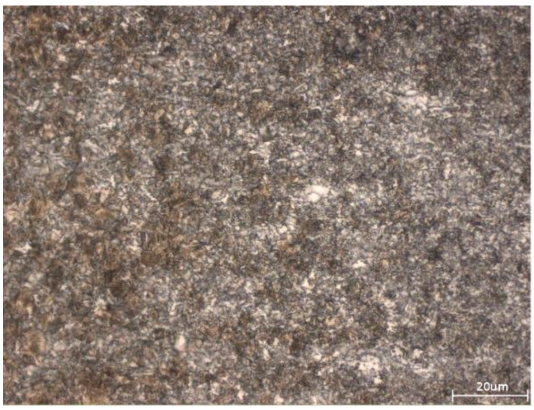
3. RESULTS AND DISCUSSION

The microstructure investigations were carried out in both fusion and heat affected zones. The microstructures of the fusion zone for DP, CP and TRIP steels are presented in Fig. 2.

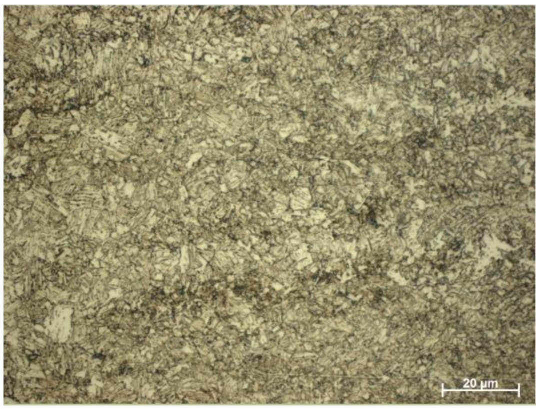
The microstructure of the fusion zone for dual phase steel is composed of lath martensite. In the case of complex phase steels the microstructure is composed of the low-carbon lath martensite and small fraction of retained austenite in shape of thin-films between martensite laths. The morphology of this lath martensite is defragmented (Fig. 2d) what indicates that tempering-like processes could take place during the welding. The microstructure of the fusion zone of the TRIP steel was composed of the lath martensite with some fraction of blocky martensite and retained austenite. In this case the defragmentation of martensite can be seen as well. The retained austenite was presented as films [14]. Additionally, the fusion zone of the TRIP steel includes harmful non-metallic inclusions because of the highest amount of alloying elements with the high affinity to oxygen. Recently, Grajcar et al. [14] investigated the non-metallic inclusions in this steel. They found out that there are large and small non-metallic inclusions of globular shape. Depending on their size, the particles contain Al, Si and Mn (large size) or just Al (small size). The total amount of the alloying elements for each steel is presented in Tab. 3. Figure 3 presents the micro structure of the heat affected zone for each steel. The microstructure of the heat affected zone of dual phase steel is composed of the fine-grained martensitic-bainitic mixture with small fraction of retained austenite. Similar situation occurs in the case of complex phase steel. The morphology of the martensite shows that tempering-like processes could occur in the case of HAZ, as well (Fig. 3d). The microstructure of the TRIP steel is composed of the fine-grained martensitic-bainitic mixture. Unlike in the fusion zone, the morphology is mainly lath-like. The retained austenite is embedded in the microstructure of the heat affected zone in shape of thin films between martensitic and bainitic laths [14]. The HAZ of all steels is free of non-metallic inclusions.

Table 3. Sum of alloying elements with the high affinity to oxygen for each steel

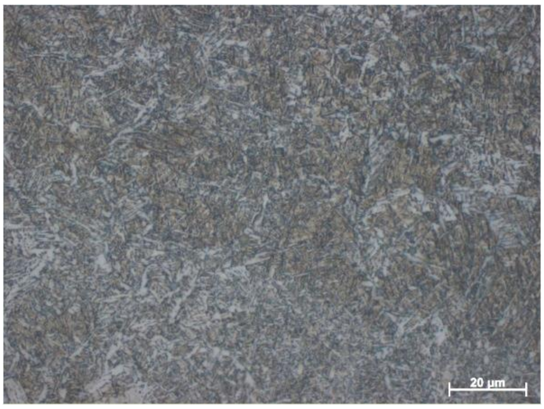
Steel	Elements	Mn	Si	Al	Total content
DP	[wt.%]	1.50	0.20	0.04	1.74
CP		1.72	0.56	0.29	2.57
TRIP		1.55	0.87	0.40	2.82



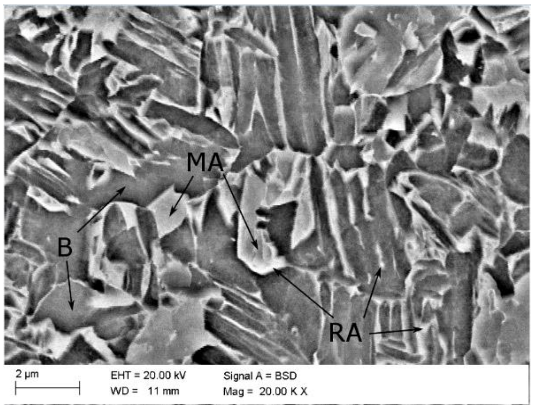
a) dual phase steel



b) complex phase steel



c) TRIP steel



d) SEM photo of CP steel

Fig. 3 Microstructure of the HAZ for investigated steels; RA - retained austenite, MA - martensitic-austenitic islands, B - bainite

4. CONCLUSION

The use of the twin-spot laser welding increases the cooling time of welded material, what affects positively the microstructure and mechanical properties of the welded joints. The FZ and HAZ martensitic microstructures of the dual phase, complex phase and TRIP steels show the effects of tempering-like processes caused by the second beam. This phenomenon decreases the hardness of welds and, finally, it prevents cracking during exploitation. The martensite of the HAZ is more fine-grained and blocky-like compared to the tempered martensite occurring in the fusion zone. The FZ of TRIP steel includes complex and pure non-metallic inclusions due to the highest amount of elements with the high affinity to oxygen.

ACKNOWLEDGEMENTS

The financial support of the Ministry of Science and Higher Education (subvention No. 7430/E-367/M/2016) for young scientists and PhD students is gratefully acknowledged.
The authors would like to thank Dr S. Stano and Dr M. Różański of Welding Institute in Gliwice (Poland) for their help with laser processing.

REFERENCES

[1] K. Radwanski, A. Wrozyna, R. Kuziak, Role of the advanced microstructures characterization in modeling of mechanical properties of AHSS steels. Materials Science and Engineering: A, 639 (-), 2015: pp.567-574.

[2] D. Krizan, K. Spiradek-Hahn, A. Pichler, Relationship between microstructure and mechanical properties in Nb-V microalloyed TRIP steel. Materials Science and Technology, 31 (6), 2015: pp.661-668.

[3] Z. Gronostajski, A. Niechajowicz, S. Polak, Prospects for the use of new-generation steels of the AHSS type for collision energy absorbing components. Archives of Metallurgy and Materials, 55(1), 2010: pp.221-230.

[4] D. Kuc, E. Hadasik, G. Niewielski, I. Schindler, E. Mazancova, S. Rusz, P. Kawulok, Structural and mechanical properties of laboratory rolled steels high-alloyed with manganese and aluminum. Archives of Civil and Mechanical Engineering, 12 (3), 2012: pp.312-317.

[5] A. Lisiecki, Welding of thermomechanically rolled fine-grain steel by different types of lasers. Archives of Metallurgy and Materials, 59 (4), 2014: pp.1625-1631.

[6] S.S. Nayak, E. Biro, Y. Zhou, Laser welding of advanced high-strength steels (AHSS), in: M. Shome, M. Tumuluru (Eds.), Welding and Joining of Advanced High Strength Steels (AHSS), Woodhead Publishing, 2015: pp.71-92.

[7] K. Banerjee, Improving weldability of an advanced high strength steel by design of base metal microstructure. Journal of Materials Processing Technology, 229 (-), 2016: pp.596-608.

[8] Y. Miyashita, Developments in twin-beam laser welding technology, in: S. Katayama (Ed.), Handbook of Laser Welding Technologies, Woodhead Publishing, 2013: pp.434-458.

[9] M. Morawiec, M. Różański, A. Grajcar, S. Stano, Effect of dual beam laser welding on microstructure-property relationships of hot-rolled complex phase steel sheets. Archives of Civil and Mechanical Engineering, 17 (1), 2017: pp.145-153

[10] E. Capello, P. Chiarello, E. Piccione, B. Previtali, Analysis of high power CO_2 dual beam laser welding, in: E. Kulianic (Ed.), Advanced Manufacturing System and Technology, Springer, 2002: pp.473-480.

[11] J. Milberg, A. Trautmann, Defect-free joining of zinc-coated steels by bifocal hybrid laser welding. Production Engineering Research and Development, 3 (1), 2009: pp.9-15.

[12] S. Yan, Z. Hong, T. Watanabe, T. Jingguo, CW/PW dual-beam YAG laser welding of steel/aluminum alloy sheets. Optics and Lasers in Engineering, 48 (7-8), 2010: pp.732-736.

[13] M. Różański, M. Morawiec, A. Grajcar, S. Stano, Modified twin-spot laser welding of complex phases steel. Archives of Metallurgy and Materials, 61 (4), 2016: pp.1999-2008.

[14] A. Grajcar, M. Różański, M. Kamińska, B. Grzegorczyk, Study on non-metallic inclusions in laser-welded TRIP-aided Nb-microalloyed steel. Archives of Metallurgy and Materials, 59 (3), 2014: pp.1163-1169.

The shorter version of this research was presented at the "22nd International Seminar of PhD Students SEMDOK 2017", 25-27 January 2017, Western Tatras, Zuberec, Slovakia.