MendelNet

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Editors:

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Lenka Prokešová

Proceedings of 28th International PhD Students Conference

10 November 2021, Brno, Czech Republic

Mendel University in Brno
Faculty of AgriSciences

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PREFACE

Each year, the editors of the volume you are about to read are tasked with the responsibility of putting a coherent form to the proceedings from MendelNet, the international PhD Students Conference of the Faculty of AgriSciences of Mendel University in Brno.

The event which reached, this year, on November 10, 2021, its 28th edition, is traditionally aimed at both under and postgraduate students from the Czech Republic, Europe and beyond, and proudly welcomes the participants of various professional and cultural backgrounds. And while this time the people could not gather on-site due to globally-imposed covid-19 restrictions, the conference swiftly transformed itself into a virtual and fascinating beehive of results, opinions and brand new research paths and ideas.

Here in Brno, under the spell of great genetician G. J. Mendel and the guidance of skilled senior researchers and supervisors, students can introduce, defend and discuss their scientific results while those who do not feel confident enough to present and pen their paper in English are invited to join as spectators and follow-up discussion participants.

The best submissions are, after rigorous peer-review process, collected here and range from plant and animal production to fisheries and hydrobiology to wildlife research while agroecology and rural development, food technology, plant and animal biology, techniques and technology and applied chemistry and biochemistry also belong to the core areas being investigated.

The collection as varied and huge as this can succeed only as a team effort, both on authors' and editors' side, so we would like to express our thanks and gratitude to all committees and reviewers both for their outstanding work and invaluable comments and advice.

The Editors

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Stability of intemetallic phases in the heat affected zone depending on shielding gases

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Abstract: This contribution deals with the influence of shielding gases on the parameters of MIG and MAG welds. For the experiment purposes, steels S 235 JRG1 and C45 were chosen. In the research part, welding parameters and welding conditions were proposed; based on them, a series of experiments were performed. Weld beads were subjected to metallographic analysis (samples prepared according to ČSN ISO 4967), from which the heat-affected zone and metal structure were determined. The melting bath area was not analyzed. Furthermore, in the heat-affected zone there were hardness and microhardness measured. The macrohardness of the samples was measured using the Rockwell HRB method according to ČSN EN ISO 6508 standard. The microhardness measurement was performed using Hannemann microhardness tester according to ČSN EN ISO 6507-1 standard.

Key Words: MAG, welding, depth of penetration, microstructure, hardness

INTRODUCTION

MIG (Metal Inert Gas) and MAG (Metal Active Gas) welding are currently one of the most widely used welding methods and have significant advantages over other methods, such as welding of various materials (Poláková et al. 2018). These technologies are also advantageous for the application of carbide welds (Votava et al. 2019). An important advantage of this method is the possibility of automation, which is used mainly in the car production. Other advantages are well-adjustable welding parameters, the possibility of controlled metal transfer and the possibility of combination with other welding methods, such as TIG (Tungsten Inert Gas).

To meet the required parameters of the welded joint, it is necessary to observe process parameters, such as current, voltage, torch feed rate, amount and type of used shielding gas and the metal transfer method. The choice of shielding gas is an integral part of the welding process design. The gas composition significantly affects the shape, microstructure and mechanical properties of welded joints (Boiko and Avisans 2013)

Welding is used in almost all industries; from the largest structures of bridges, buildings and ships to underwater welding, welding in space conditions and the construction of oil and gas pipelines, where high demands on the welded joint strength and tightnes are placed (Sartori et al. 2017)

The main disadvantages include influencing the microstructure and material properties in the heat-affected zone, deformation of the weldment and usually the need for further heat treatment. An important parameter in the heat treatment of weldments is the cooling rate and the cooling medium itself (Šmak et al. 2020b).

MATERIAL AND METHODS

The experimental part deals with MIG/MAG welding technology. Steel S 235 JRG1 and C45 were chosen for the production of weldments. These two materials represent standard structural steel with guaranteed weldability (S 235 JRG1), but also steel with difficult weldability (C45). The reason for difficult weldability is the higher percentage of carbon. The inert gas Argon 4.6 with a purity of 99.99% was chosen as the technical gas for the MIG method and the active gas CO_2 for the MAG method. The research carried out (Tomc and Tušek 2013) shows that, in additionto the shielding gas composition, the shape of the weld formed by the MIG/MAG methods is also significantly affected by the nozzle geometry which forming the shielding gas stream around the forming weld pool.

Based on the performed metallographic analysis, the weldment heat-affected zone was monitored, but also the microhardness of individual structural phases was measured. The following tests were performed to determine basic characteristics of weldment:

1. measurement of base material hardness, heat affected zone and weld metal by HRB method,
2. measurement of microhardness using metallographic microscope Neophot 21 according to ČSN EN ISO 6507-1,
3. metallographic analysis of the heat affected zone.

A Picomig 180 plus TKG pulse welding unit with the following parameters was used for sample preparation:

- welding current: 170 A,
- welding voltage: 26.5 V,
- wire feed: 11.5 m/min; wire diameter: 0.8 mm.

Autrod 12.51 welding wire was chosen as an additional material for both welding technologies. The mechanical properties of the given material are given in Table 1.

Table 1 Autrod 12.51 wire mechanical properties

Welding method	Shielding gas	Rm	$R_{p0.2}$	As	KV +20°C]	KV -20 °C
MIG	Argon	540 MPa	450 MPa	25%	110 J	90 J
MAG	CO_2	560 MPa	470 MPa	26%	130 J	70 J

Characteristic of tested materials

S 235 JRG1

This steel is intended primarily for the weldments production. Its chemical composition guarantees safe weldability. It is a standard structural steel, where due to the small amount of carbon it is not possible to perform heat treatment with significant changes in structural phases. See Figure 1.

C45

This material is suitable for tempering and surface hardening. It is a structural steel with a higher percentage of carbon. Based on the metallographic analysis, see Figure 2, this material can be characterized in its natural state as a pearlitic-ferritic structure with a majority of pearlite. The pearlitic lamellae dispersity corresponds to an amount of carbon which is above 0.4%. The chemical composition of C45 steel and S 235 JRG1 steel is given in Table 2.

Figure 1Microstructure of steel S 235 RG1

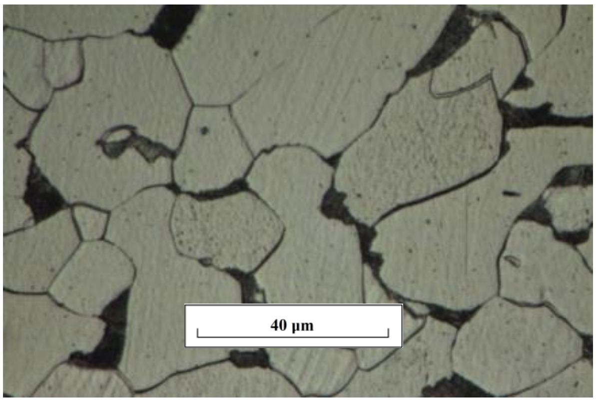


Figure 2 Microstructure of steel C45

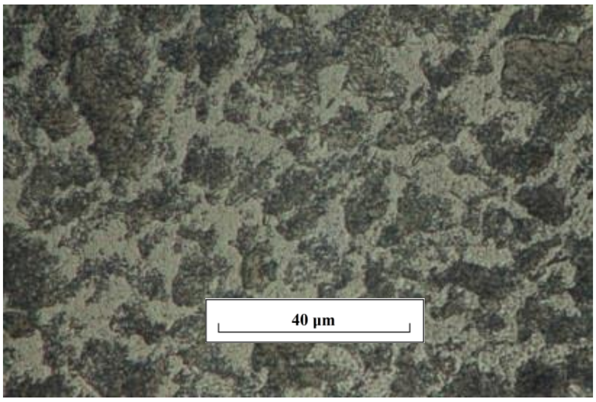


Table 2 Chemical composition of used steels

Steel	Chemical composition					
	C	CE	Mn	Si	P_{max}	S_{max}
S 235 JRG1	0.17%	0.25%	-	-	0.045%	0.045%
C45	0.45%	0.53%	0.5%	0.17%	-	-

RESULTS AND DISCUSSION

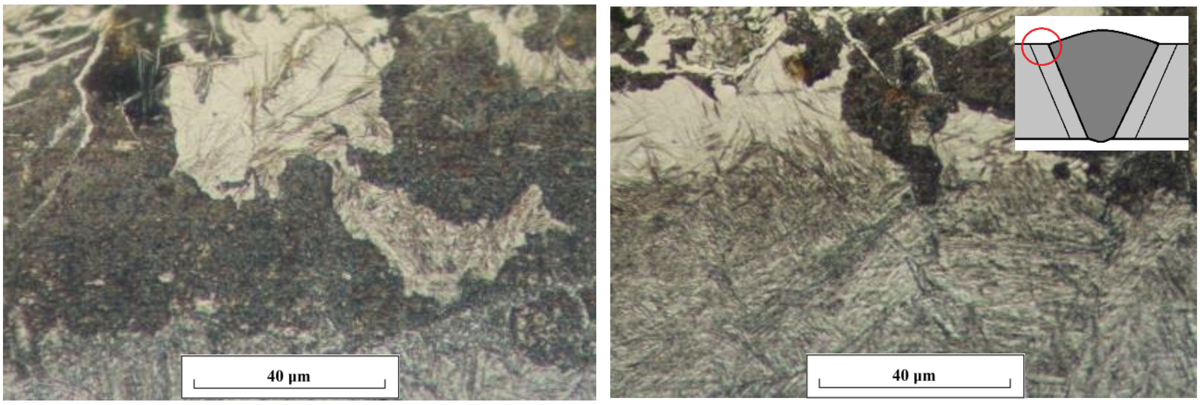
In the weld heat-affected zone, there is a greater risk of brittle structure formation, which negatively affects the mechanical properties of the steel and can also contribute with poor adhesion of inorganic anti-corrosion systems, mainly zinc coatings (Votava et al. 2018, Nascimento et al. 2012). Announced that due to exothermic reactions between O_2 and the elements contained in the electrode and the melting bath (especially iron and carbon), the arc temperature is higher for gas mixtures with higher O_2 content (active gases). In addition to this temperature increase effect, the different thermal conductivity of the shielding gases must be taken into account. This higher thermal conductivity means a greater supply of heat to the weld pool. The following changes can be identified: a decrease in the weld bead and an increase in the transition structure intensity between the weld metal and the base material. Another set of changes occurs at the microstructure level. Changes occur depending on the carbon content and cooling rate of the weldment.

Metallographic analysis

S 235 JRG1

The heat-affected zone of S 235 JRG1 steel can be characterized in both welding methods as very gradual, without enormous changes. The dendrites formed in the weld metal pass into the base material affected by plastic deformations caused by rolling. The weld metal is not affected with the base material and it can be stated that it retains a similar chemical composition as the additive material. Since these structural phases are formed from the melt, ferritic particles are particularly evident. However, the Widmanstätten structure, which was identified in the toe region created by the MAG method, can be problematic, see Figure 3. Widmanstätten structures were found in the upper layers of the weld transition area (toe) between the base material and the weld metal. With the MAG method, due to higher temperatures, carbon segregates into the form of needles. These phases are created as a result of an undesired heat-stress during the welding process or material separation by flame (Šmak et al. 2020a). These conditions do not occur with the MIG method.

Figure 3 Widmanstätten structute in heat-affected zone, S 235 JRG1 steel, MAG



C45

When using the MIG method, the transition area is much more gradual than for MAG method. The weld metal is fundamentally affected by the content of carbon in the base material. According to the performed metallographic cuts, it is obvious that the C45 steel undergoes fundamental structural changes in the heat-affected zone. It is mainly the formation of brittle unstable phases especially bainite, which can initiate cracks in the area. However, no pure martensitic structure was found in the samples. When using an inert gas, the transition structure consists of predominantly homogeneous fractions. The MAG method is characterized by a heterogeneous compound. In contrast, in the research performed (Ilic et al. 2020), an toughness analysis of welds performed with inert and active gases on high-strength steel S690QL was performed. Research has shown higher values of impact energy in samples welded with active gas. From this it can be clearly deduced that the resulting mechanical properties are strictly determined by both the shielding gas and the welded steel chemical composition.

Hardness measurement

Macrohardness measurements were performed using the HRB method, because with the use of this method it is possible to measure in the low range of hardnesses, when the use of the HRC method would be inappropriate, due to the low hardness of the measured materials. With this method, it is not possible to recognize changes in the microstructure, such as the Widmanstätten structure. However, the HRB method makes it possible to determine relatively accurately the overall condition of the analyzed area.

For C45 steel, an increase in values was expected due to the higher carbon content. As the base material was natural steel, the measured values are very similar to S 235 JRG1. The values measured in the heat affected zone are about 10 units higher than the value of the base material. Research performed by (Sayed et al. 2021) shows a very good resistance of C45 steel to hydrogen embrittlement and cold cracking. This effect is ensured by the use of electrodes with a low hydrogen content and controlled cooling of the weldment.

The correlation between microhardness and macrohardness values is limited. The HRB method uses a significantly higher sample area for hardness analysis. The resulting value is the summary value of hardness from the entire measured area. Microhardness measurement methods are used to measure the hardness of individual structural phases. The measured hardness values for S 235 JRG1 and C45 steel are recorded in Table 3.

Table 3 HRB measurement, S 235 JRG1 and C45 steel weldments

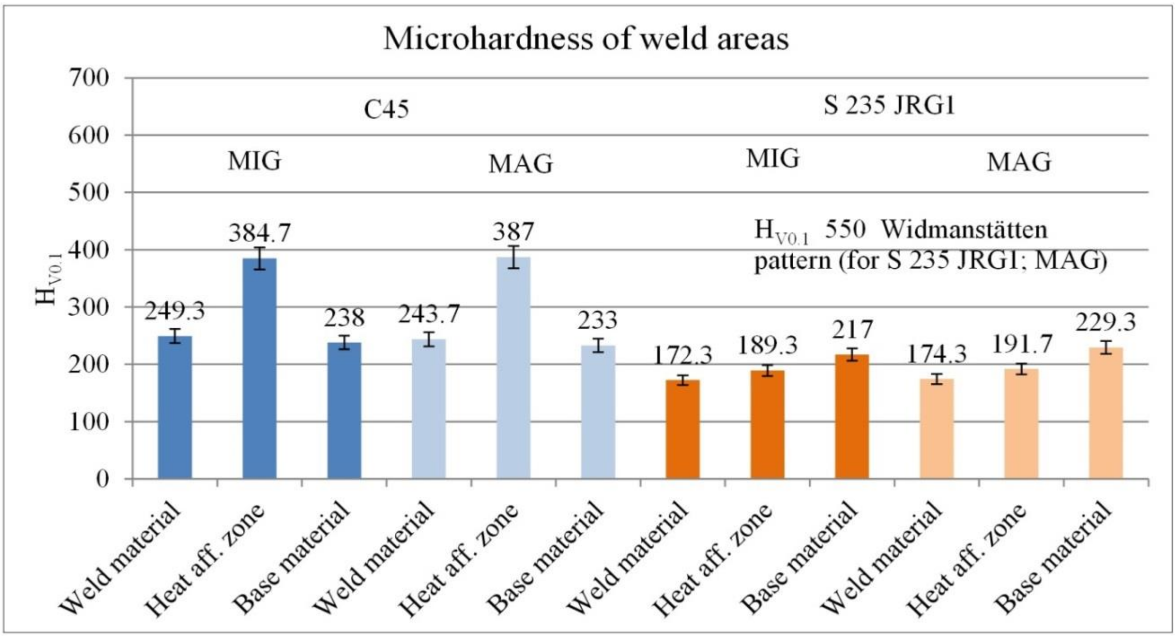
Welding method	Measured area	S 235 JRG1			C45		
		Average HRB	Standard deviation HRB	Var. coefficient	Average HRB	Standart deviation HRB	Var. coefficient
MIG	Weld material	79.7	2.1	2.6%	83.7	2.9	3.4%
	Heat aff. zone	81.0	2.2	2.7%	98.0	1.4	1.4%
	Base material	84.7	0.5	0.6%	86.7	2.1	2.4%
MAG	Weld material	76.7	2.1	2.7%	84.0	2.2	2.6%
	Heat aff. zone	81.7	2.5	3.1%	101.0	3.3	3.2%
	Base material	83.0	0.8	1.0%	87.0	1.4	1.6%

Microhardness measurement

Microhardness measurements were performed using a Hannemann microhardness tester. This tester is a part of the Neophot 21 metallographic microscope. The Vickers method was used for the microstructure analysis. The measurement was realised according to ČSN EN ISO 6507-1 standard.

The microhardness values of the individual areas in steels S 235 JRG1 and C45 are shown in the Figure 4. Since the basic C45 steel is already formed by a pearlitic-ferritic structure, there is also an increase in hardness values compared to the steel S 235 JRG1. According to the performed analysis, a clear increase in the structural phases microhardness in the heat-affected zone was demonstrated with values of approx. 384 $\mathrm{H_{V0.1}}$. Although these values are not adequate to the phases of the martensitic structure, the risk of microcracks in the heat-affected zone can be clearly predicted. (Silva Costa et al. 2020) mentions the control of weld metal transfer as a possibility to regulate the heat affected zone size.

Figure 4 Microhardness of weld areas



CONCLUSION

In the presented contribution, MIG and MAG methods for the production of weldments from S 235 JRG1 and C45 steel were analyzed.

Although the same additional material was used in both methods, the different mechanical properties of the weld were caused by the reaction between the shielding gas and the molten bath. Especially due to exothermic reactions between O_2 and the elements contained in the melting bath (iron and carbon), the arc temperature is higher for active gases which causes changes in the microstructure. The research clearly confirmed this.

Metallographic analysis of S 235 JRG1 steel shown the smooth dendrite flow from the melt bath into the base material. Since both the weld metal and the base material do not have a carbon content higher than 0.25%, the heat-affected zone is predominantly a ferritic compound. In the case of S 235 JRG1 steel, the presence of the Widmanstätten structure was detected using the MAG method in the heat-affected zone.

Following differences have already been noted in the analysis of C45 steel weldments. Although the influence of the shielding gas on the weldment quality itself was not proven, there is the formation of brittle bainitic structural phases not only in the weld metal itself, but especially in the heat affected zone (avg. 387 $H_{V0.1}$). Although the thickness of the weldment material guarantees sufficient heat treatment, transient structural phases with an average microhardness of approx. 384 $H_{V0.1}$ occur at the weld interface and the base material. The microhardness values for the active gas are approximately 10% higher than for the inert gas. Shielding gas for the MIG method is more expensive, but it eliminates the formation of dangerous brittle structures in the transition area.

This contribution was based mainly on the analysis of the weld microstructure. Impact testing could be performed to further describe the mechanical properties. The author considers these tests as a possibility for further research.

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REFERENCES

Boiko, I., Avisans, D. 2013. Study of shielding gases for MAG welding. Materials Physics and Mechanics [Online], 16: 126–134. Available at: https://www.ipme.ru/e-journals/MPM/no_21613/MPM216_04_boiko.pdf. [2021-08-15].

Ilic, A. et al. 2020. Analysis of Influence of the Welding Procedure on Impact Toughness of Welded Joints of the High-Strength Low-Alloyed Steels. Applied Sciences [Online], 10(7): 590–600. Available at: https://www.mdpi.com/2076-3417/10/7/2205/htm. [2021-07-11].

Nascimento, A. et al. 2012. Effect of waveform and shielding gas on melting rate and bead geometry for MIG/MAG-PV. Soldagem e Inspecao [Online], 17(1): 40–48. Available at: https://www.scielo.br/j/si/a/Tyv8cCzqBnJrMkYX8d99yzS/?lang=pt. [2021-08-01].

Poláková, N. et al. 2018. TIG welding of stainless steel and titanium with additive AG 104. In Proceedings of International PhD Students Conference MendelNet 2018 [Online]. Brno, Czech Republic, 07–08 November, Brno: Mendel University in Brno, Faculty of AgriSciences, pp. 468–471. Available at: https://mnet.mendelu.cz/mendelnet2018/mnet_2018_full.pdf. [2021-07-25].

Sartori, F. et al. 2017. A Comparative Analysis of Different Versions of the MIG/MAG Process Modern Variants for the Root Pass in Orbital Welding. Soldagem e Inspecao [Online], 22(4): 442–452. Available at: https://www.scielo.br/j/si/a/jHp4wLYJfNZmj7QRFsphPHm/?lang=pt. [2021-08-17].

Sayed, A. et al. 2021. Mechanical and microstructural testing of C-45 material welded by using SMAW and GMAW process. Materials Today: Proceedings [Online], 38(1): 223–228. Available at: https://www.sciencedirect.com/science/article/pii/S2214785320351142?via%3Dihub. [2021-08-18].

Šmak, R. et al. 2020a. Influence of phase structures on cutting surface quality and cutting tool degradation. In Proceedings of International PhD Students Conference MendelNet 2020 [Online]. Brno, Czech Republic, 11–12 November, Brno: Mendel University in Brno, Faculty of AgriSciences, pp. 474–479. Available at: https://mendelnet.cz/pdfs/mnt/2020/01/85.pdf. [2021-07-21].

Šmak, R. et al. 2020b. The cooling media influence on selected mechanical properties of steel. Acta Technologica Agriculturae [Online], 23(4): 183–189. Available at: https://www.sciendo.com/article/10.2478/ata-2020-0029. [2021-08-15].

ÚNMZ. 2018. Kovové materiály – Zkouška tvrdosti podle Vickerse. Část 1: Zkušební metoda. ČSN EN ISO 6507-1. Praha: Úřad pro technickou normalizaci, metrologii a státní zkušebnictví.

ÚNMZ. 2018. Kovové materiály – Zkouška tvrdosti podle Rockwella. Část 1: Zkušební metoda. ČSN EN ISO 6508-1. Praha: Úřad pro technickou normalizaci, metrologii a státní zkušebnictví.

ÚNMZ. 2015. Ocel- Stanovení obsahu nekovových vměstků – Mikrografická metoda. ČSN ISO 4967. Praha: Úřad pro technickou normalizaci, metrologii a státní zkušebnictví.

Tomc, J., Tušek, J. 2013. Description of flow of shielding gases through nozzles in MIG/MAG and TIG welding processes. Science and Technology of Welding and Joining [Online], 9(3): 260–266. Available at: https://www.tandfonline.com/doi/abs/10.1179/136217104225012184. [2021-08-20].

Votava, J. et al. 2019. Využití tvrdokovových návarů u sklízečů cukrové řepy. Listy cukrovarnické a řepařské [Online], 135(9): 297–302. Available at: http://www.cukr-listy.cz/on_line/2019/PDF/297-302.pdf. [2021-07-30].

Votava, J. et al. 2018. Anti-corrosion systems in vehicles for the transportation and application of fertilizers. Metallic Materials [Online], 56(2): 131–136. Available at: https://doi.org/10.4149/km_2018_2_131. [2021-08-19].

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