

INFLUENCE OF SHIELDING GAS ON FUME AND GAS EMISSION DURING ARC WELD BRAZING OF STEEL SHEETS WITH COATINGS

Received – Prispjelo: 2014-03-04

Accepted – Prihvaćeno: 2014-08-31

Original Scientific Paper – Izvorni znanstveni rad

The article presents the results of research into the fume and gas emission during MIG/MAG arc weld brazing. Investigations were conducted for hot - dip coated steel sheets with zinc and zinc and iron alloy coatings. Steel grades of DX 54D Z 100 MBO and DX 54D ZF 100 RBO were used during research. ARC shielding gases applied were Ar + O₂, Ar + CO₂, Ar + H₂ and Ar + CO₂ + H₂ gas mixtures. Analysis of the results covers the influence of chemical composition of shielding gas effect on the emission rate of total fume, nitrogen oxides and carbon monoxide.

Key words: welding, steel, MIG/MAG weld brazing, fume and gas emission, protective coated sheet

INTRODUCTION

Welding and weld brazing processes are associated with the emission of welding fume - the mixture of dust and gases, the source of which is high temperature and the radiation of welding arc. Weld brazing of steel plates with zinc coatings is connected with the significant zinc emission due to the fact that the essence of this process is not melting of parent metal (steel sheet) but only melting of electrode wire and coating. Zinc fumes can be the reason for metal fume fever – occupational disease of flu - like symptoms which disappear within several days [1]. Gas impurities consist of mainly nitrogen oxides (NO_x) and carbon monoxide (CO). Long-lasting employee exposure to welding fumes causes various types of respiratory system diseases.

Research directed towards searching methods of the limitation of fume emission during welding processes conducted in many research centres [2 - 5], including Instytut Spawalnictwa [6], has established that the possibility of selecting shielding gases of various chemical compositions is one of the important ways to reduce the work environment exposure to chemical substances. Replacing one-component gas (pure argon or carbon dioxide) with gas mixtures significantly reduces the emission of fumes and gases during the process [6]. This trend towards the modification of welding conditions in the aspect of reducing the emission of pollution is associated with the availability of shielding gases of new and improved compositions.

THE SCOPE OF RESEARCH

The research aimed at the determining the fume and gas emission rate while MIG/MAG arc weld brazing of

protective coated steel sheets and establishing the relations between the chemical composition of shielding gas and pollutant emission rates [7]. Research was conducted for six various shielding gases. They included argon and its mixtures with oxygen (Ar + 2 % O₂), carbon dioxide (Ar + 2 % CO₂), hydrogen (Ar + 2 % H₂) as well as carbon dioxide and hydrogen (Ar + 2 % CO₂ + 1 % H₂ and Ar + 3 % CO₂ + 1 % H₂). Gases of these chemical compositions are regarded as the most favourable process shielding gases for use particularly in „classical” MIG/MAG weld brazing processes [2, 5].

Parent metal used in this research was 1,5 mm thick hot - dip coated steel of DX 54D Z 100 MBO and DX 54D ZF 100 RBO grades. Steel sheets were covered with zinc coating (Z 100 MBO - improved quality of the surface, oiled, coating thickness 5-12 μm) and zinc and iron alloy coating (ZF 100 RBO - improved quality of the surface, oiled, coating thickness 5-12 μm). The chemical composition of parent metal is shown in Table 1. During research one set of weld brazing parameters, constant for all gases, was determined. The technological parameters for testing the emission of pollutants are presented in Table 2. CuSi3Mn filler metal in the form of a wire of the diameter of 1 mm used for weld brazing contains: 2,80 , 2,95 % Si, 0,75, 0,95 % Mn, the rest - Cu.

Table 1 **Parent metal used in research: chemical composition / mass % max. [7]**

Steel grade	C	Si	Mn	P	S
DX 54D Z 100 MBO / ZF 100 RBO	0,12	0,50	0,60	0,10	0,045

Research station for testing the emission of fume and gas during MIG/MAG arc weld brazing was presented in the Figure 1.

J. Matusiak, J. Wyciślik, Institute of Welding, Gliwice, Poland

Table 2 **Technological parameters for research into emission of pollutants [7]**

Denotations in the table: I – welding current, U – arc voltage, V_w – wire feed rate, V_{ws} – welding speed

Technological parameters of process			
I / A	U / V	$V_w / m/min$	$V_{ws} / mm/min$
70	13,7	3,5	190
100	16,7	5,3	320
130	17,7	7,0	620



Figure 1 Research station for testing fume and gas emission while MIG/MAG arc weld brazing

INFLUENCE OF SHIELDING GAS ON FUME AND GAS EMISSION

Research has revealed that the composition of shielding gas significantly influences on the fume emission rate in MIG/MAG arc weld brazing. For six different shielding gases being tested it has been found that the highest emission of total fume is associated with the application of argon for the arc shielding. This regularity has been revealed for both grades of parent metals, i.e. steel covered with zinc coatings of Z and ZF types. Due to the fact that argon is the most commonly used for the arc shielding in the “classical” processes of MIG/MAG arc weld brazing, the comparative analysis of the effect of the selected shielding gases was conducted for this shielding gas.

The greatest emission of the total fume during MIG/MAG weld brazing of zinc coated steel using various shielding gases occurs in case of argon shielding gas (Figure 2).

The application of three-component mixtures of argon and carbon dioxide and hydrogen is the most favourable for reduction of fume emission. Lower emission rate of the total fume occurs for mixture $Ar + 2\% CO_2 + 1\% H_2$, if compared to argon application this mixture can reduce the fume emission even by 50 % for weld brazing of steel protected with coatings of Z and ZF type. Mixtures: $Ar + 2\% O_2$, $Ar + 2\% CO_2$ and $Ar + 2\% H_2$ also influence on the reduction of fume emission during MIG/MAG weld brazing. The level of the reduction of the fume emission rate compared to weld brazing in argon shielding gas in case of the above men-

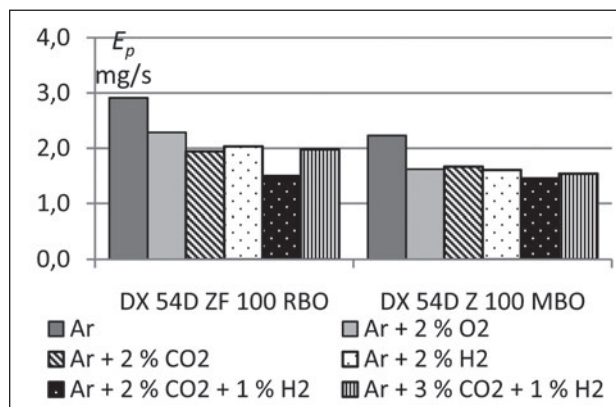


Figure 2 Influence of shielding gas composition on fume emission during MIG/MAG weld brazing of steel with protective coatings. ($I = 70 \div 130 A$; $U = 13,7 \div 17,7 V$; $V_w = 3,5 \div 7,0 m/min$; $V_{ws} = 190 \div 620 mm/min$)

tioned two-component mixtures is very similar and equals to 30 % approximately.

Research has revealed that composition of shielding gas during MIG/MAG arc weld brazing also influences on the emission rate of nitrogen oxides. Among six shielding gases being tested the greatest emission of NO_x occurred when argon and mixture $Ar + 2\% O_2$ were applied for the arc shielding. The analysis of the medium values of the emission of NO_x determined for all range of tested technological parameters has revealed that during braze welding of steel with Z type zinc coating the highest emission of NO_x occurs when argon is used as the arc shielding gas. In turn, during weld brazing of steel with ZF type coating $Ar + 2\% O_2$ causes the highest emission of nitrogen oxides. Moreover, the gas mixture $Ar + 2\% CO_2$ was characterised by the lowest NO_x emission in braze welding of coated steel (Figure 3).

If compared to weld brazing in Ar shielding gas the introduction of this mixture caused 4,5 – fold reduction on average of the emission rate of nitrogen oxides for steel covered with zinc coating of Z type and over 6,5 – fold reduction in case of steel protected with the coating of ZF type. The application of $Ar + CO_2 + H_2$ three-

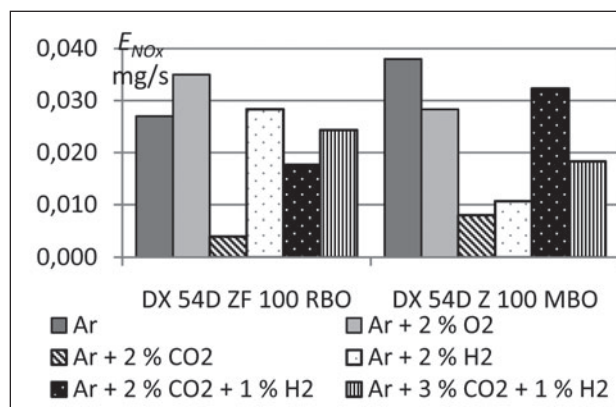


Figure 3 Influence of shielding gas composition on the emission of nitrogen oxides during MIG/MAG weld brazing of steel with protective coatings

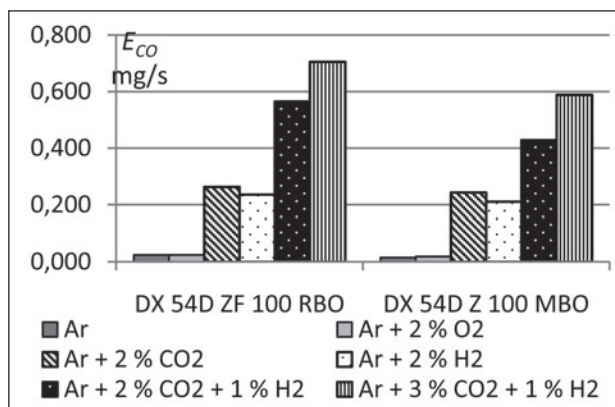


Figure 4 Influence of shielding gas composition on the emission of carbon monoxide during MIG/MAG weld brazing of steel with protective coatings.

component arc shielding gas mixtures also favours the reduction of NO_x emission if compared with weld brazing in Ar shielding.

The analysis of research results has revealed the influence of chemical composition of shielding gas on the emission of carbon monoxide during MIG/MAG braze welding of protective coated steel. Mixtures Ar + CO₂ + H₂ used for arc shielding cause approximately 25 ÷ 30 – fold increase of the CO emission if compared with emission in braze welding in Ar shielding gas. Ar + 2 % CO₂ mixture also causes approximately 10 ÷ 15 – fold increase in CO emission if compared with one-component arc shielding. Application of Ar + 2 % H₂ shielding gas during weld brazing increases the emission of carbon monoxide (like for Ar + 2 % CO₂ active gas) approximately 9 ÷ 14 times if compared with the emission during weld brazing in argon shielding. The lowest carbon monoxide emission occurs for argon and Ar + 2 % O₂ mixture, and CO emission rates for these two shielding gases are very similar (Figure 4).

The analysis of research results has revealed that like for the arc welding in a shielding gas of various structural materials, during MIG/MAG weld brazing of coated steels it is impossible to select and apply a shielding gas of one universal chemical composition enabling the limitation of both fume and harmful gases emission. The influence of shielding gas on the emission is associated with the chemical, physical and energy properties of the particular gas mixture. For argon, being a very favourable technological shielding gas for weld brazing with CuSi3Mn filler metal of zinc coated steel [2, 5], in case of the problem of the emission of pollutants into work environment the assessment of this gas is not unambiguously positive. Application of argon causes the greatest emission of fume and nitrogen oxides but also usage of argon for arc shielding favours the low emission of carbon monoxide. Mixtures with low content of CO₂ or O₂ from technological point of view improve stability of weld brazing process as well as quality and aesthetics of weld brazed joints [2, 5]. Oxygen and carbon dioxide affect positively the

stabilisation of electric arc, significantly low heat input and spatter reduction. Oxidising gases (oxygen and carbon dioxide) can intensify the process of oxidising of the zinc coating on steel. In the aspect of work environment these gas mixtures cause the reduction of the total fume emission rate. In the case of Ar + 2 % CO₂ they reduce nitrogen oxides emission while Ar + 2 % O₂ mixture leads to the greatest emission of nitrogen oxides. In turn, Ar + 2 % O₂ mixture, because of its chemical composition, contributes to the substantial reduction of carbon monoxide emission rate. Two- and three-component mixtures with 1 ÷ 3 % hydrogen addition technologically ensure a stable arc burning, lack of spatter and favourable braze weld appearance. H₂ additive in the mixture can however cause oxidising of the braze weld face and these mixtures can have an adverse thermal influence on the zinc coating in the weld area. From the work environment protection viewpoint three-component mixtures of argon with carbon dioxide and hydrogen help to limit the emission of fume and nitrogen oxides. Unfortunately the mixtures containing hydrogen increase the emission of carbon monoxide during MIG/MAG weld brazing of zinc coated steel.

While estimating the influence of weld brazing process on work environment it has been revealed that all tested pollutants affect health and work safety of employees (Table 3).

Table 3 Influence of a chemical composition of shielding gases on reduction of pollutant emission during MIG/MAG weld brazing of zinc coated steel

Shielding gas	Emission reduction		
	Fume	NO _x	CO
Ar	o	o	+++
Ar + 2 % O ₂	+	o	+++
Ar + 2 % CO ₂	++	+++	o
Ar + 2 % H ₂	+	++	o
Ar + 2 % CO ₂ + 1 % H ₂	+++	++	-
Ar + 3 % CO ₂ + 1 % H ₂	++	++	-

- - not satisfactory
 o - neutral
 + - medium
 ++ - good
 +++ - very good

However it should be noted that the fume emission is definitely a dominating factor being harmful to the workers' health. For environmental work conditions during weld brazing of coated steel the high content of zinc compounds in the fume is of a great importance. The content of zinc in fume is running about 42 - 43% during joining steel sheets with ZF type coating and 37 - 38% during joining steel sheets with Z type coating [7]. When taking into consideration the influence of the fume emitted during arc weld brazing of zinc coated steel on the human organism, the selection of the shielding gas should be directed towards the reduction just of the fume emission into work environment.

CONCLUSION

Research results and their analysis have enabled drawing the following conclusions:

- In MIG/MAG weld brazing of coated steel it is impossible to select and apply a shielding gas of one universal chemical composition enabling reduction of both fume and gas emission. The influence of shielding gas on the emission of pollutants is associated with chemical, physical and energy properties of the given gas mixture.
- The highest fume emission rate during weld brazing of zinc coated steel using CuSi3Mn filler metal occurs when argon is being used for the arc shielding. The introduction of Ar + CO₂ + H₂ and Ar + O₂ and Ar + CO₂ gas mixtures affects the limiting the total fume emission to the work environment.
- The most favourable results in the aspect of the modification of conditions for MIG/MAG weld brazing aimed at the reduction of the fume emission, can be obtained through the application of arc shielding mixtures containing argon with carbon dioxide and hydrogen, e.g. Ar + 2 % CO₂ + 1 % H₂.
- In MIG/MAG weld brazing of coated steel using CuSi3Mn filler metal the application of Ar + 2 % CO₂ arc shielding gas unquestionably enables the greatest reduction of the nitrogen oxides emission rate. The highest NO_x emission rate is associated with weld brazing in argon and Ar + 2 % O₂ mixture shielding gases.
- Application of Ar + CO₂ + H₂ and Ar + CO₂ gas mixtures for the arc shielding in weld brazing causes multiple growth of carbon monoxide emission if compared to the Ar one-component shielding gas. The lowest carbon monoxide emission rate occurs for argon and Ar + O₂ gas mixture.

- The fact of very high content of zinc compounds in fume is of great importance for environmental work conditions in weld brazing of coated steel. Fume generation is a definitely dominating factor being hazardous for a human health. The selection of the shielding gas composition in MIG/MAG braze welding should be directed towards the reduction of the fume emission into work environment.

REFERENCES

- [1] T. Wittczak, J. Walusiak, C. Pałczyński, Welding-related respiratory diseases. *Medycyna Pracy*, 60 (3) (2009), 201-208. (<http://medpr.imp.lodz.pl>)
- [2] N. Knopp, R. Killing, Arc brazing – innovative, safe and economical. EWM HighTec.Welding, <http://www.ewm-sales.co.uk/downloads/wm023401.pdf>
- [3] A. Rabinkin, V. Defelice, Examining GMA brazing of galvanized steel sheet joints for automotive industry. *Brazing and soldering today – technology news. Welding Journal*, 9 (2006), 64-66.
- [4] L. Quintino, G. Pimenta, D. Iordanescu, R. Miranda, N. Pepe, MIG brazing of galvanized thin sheets for automotive industry. *Materials and Manufacturing Processes*, 21 (2006), 63-73.
- [5] D. Iordanescu, L. Quintino, R. Miranda, G. Pimenta, Influence of shielding gases and process parameters on metal transfer and bead shape in MIG brazed joints of the thin zinc coated steel plates. *Materials and Design*, 27 (2006), 381-390.
- [6] J. Matusiak, A. Wyciślik, The influence of technological conditions on the emission of welding fume due to welding of stainless steels. *Metalurgija*, 49 (2010) 4, 307-311.
- [7] J. Matusiak, J. Wyciślik, A. Pilarczyk, Badania wpływu warunków technologicznych i materiałowych lutowania łukowego elektrodą topliwą w osłonie gazów stali z powłokami na emisję pyłu i gazów do środowiska pracy. Research Report The Polish Institute of Welding, Ma-37 (2013).

Note: The responsible translator for English language is Barbara Dobaj-Tumidajewicz – Institute of Welding, Gliwice, Poland