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PHASE ANALYSIS OF FUME DURING ARC WELD BRAZING OF STEEL SHEETS WITH PROTECTIVE COATINGS

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The article presents the results of research of the phase identification and of the quantitative phase analysis of fume generated during Cold Metal Transfer (CMT), ColdArc and Metal Inert Gas / Metal Active Gas (MIG / MAG) weld brazing. Investigations were conducted for hot - dip coated steel sheets with zinc (Zn) and zinc-iron (Zn - Fe) alloy coatings. Arc shielding gases applied during the research-related tests were Ar + O_2, Ar + CO_2, Ar + H_2 and Ar + CO_2 + H_2 gas mixtures. The analysis of the results covers the influence of the chemical composition of shielding gas on the chemical composition of welding fume.

Key words: arc weld brazing, Zn, Zn - Fe coatings, steel sheets, phase analysis of fume

INTRODUCTION

Weld brazing processes entail the generation of fume, the source of which is high temperature and welding arc radiation [1, 2]. The chemical composition of welding fume in weld brazing results from the composition of an electrode wire, the type and thickness of a protective coating, and, to a very small extent, the chemical composition of a base material [1, 3]. Weld brazing steel sheets with zinc coatings is connected with significant emissions of zinc. Chemical compositions of filler metals used in arc weld brazing processes cause welding fume to contain copper, manganese and aluminium compounds [4].

Weld brazing accompanying occupational exposure to such varied chemical substances causes a number of negative health - related reactions in various organs, yet particularly in the respiratory tract. The list of conditions attributable to work performed by a person dealing with weld brazing includes, among others, metal fume fever, bronchial asthma (both allergenic and non - allergenic), chronic obtrusive pulmonary disease, pneumoconiosis and lung cancers [5].

THE SCOPE OF RESEARCH

The primary objective for the phase identification of welding fume was to determine the correlation between the chemical composition of welding fume generated in weld brazing processes and the chemical composition of an arc-shielding gas [6, 7]. The related research was conducted for six various shielding gases included argon and its mixtures with oxygen (Ar + 2 % O_2), carbon dioxide (Ar + 2 % CO_2), hydrogen (Ar + 2% H_2) as well as carbon dioxide and hydrogen (Ar + 2 % CO_2 + 1 % H_2 and Ar + 3 % CO_2 + 1 % H_2) [1]. The gases of these chemical compositions are regarded as the most advantageous shielding gases, particularly in weld brazing processes [8, 9].

The base material used in the research-related tests was 1,5 mm thick electrolytic zinc coated steel of DX 54D grade. The steel sheets were covered with a zinc coating (Z100MBO – improved surface quality, oiled, coating thickness of 5 - 12 μm – Z type) and a zinc-iron alloy coating (ZF100 RBO improved surface quality, oiled, coating thickness of 5 - 12 μm – ZF type) [1, 10]. The phase analysis of welding fume were conducted for technological parameters presented in Table 1. A CuSi3Mn filler metal in the form of a wire having a diameter of 1 mm used for weld brazing contained 2,80 - 2,95 % Si, 0,75 - 0,95 % Mn, the rest - Cu.

As the tests concerned with emissions of pollutants were performed for two different zinc coatings, it was necessary to first assess the effect of a variable, i.e. the type of a coating, on the phase composition of fume generated during a weld brazing process. To this end, the analysis for ColdArc weld brazing of the sheet with a Zn and Zn - Fe coating was conducted. The investigation concerned with CMT and MIG / MAG weld brazing only included the analysis involving steel sheets with a Zn coating.

Table 1 **Technological parameters of weld brazing processes [1, 10]**

Method	CMT	ColdArc	MIG / MAG
I / A	90	100	100
U / V	9,8	18,2	16,7
V_w / m/s	0,097	0,097	0,088
V_{ws} / m/s	0,0065	0,0065	0,0053

I - welding current, U - arc voltage, V_w - wire feeding rate, V_{ws} - welding speed

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The tests were performed for specimens of fume deposited on measurement filters. The powder diffraction patterns were collected using a PANalytical Empyrean diffractometer with filtered Co radiation and a PIXcel detector. The analyses of the powder data were performed using PANalytical HighScore Plus software. The phases were identified according to data of the International Centre for Diffraction Data PDF 4 + base.

The Rietveld method was used to quantify the crystalline components of fume. The idea of the Rietveld method is to minimise a function which analyses the difference between a calculated diffraction pattern and experimental data. One of the results of such an analysis is the information about abundances of crystalline phase components. The structural data from PDF 4 + base of each phase were applied to calculate the theoretical diffraction patterns of multiphase fume samples. Rietveld refinements were performed using SIROQUANT™ software.

INFLUENCE OF A SHIELDING GAS ON THE CHEMICAL COMPOSITION OF FUME

The phase identification and the quantitative phase analysis of fume generated during weld brazing steel sheets with two different zinc coatings revealed that the main fume components are identical for sheets with Zn and Zn - Fe coatings and are composed of zinc, copper and manganese compounds (Figures 1 and 2). As regards weld brazing DX54D Z100MBO grade sheet, the fume contained iron compounds; wistite FeO and $FeSi_2$. The fume generated during weld brazing DX54D ZF100RBO grade sheet also contained $FeSi_2$, a ferric spinel intermetallic compound $MnFe_2O_4$ and manganese oxide Mn_3O_4. Summarising the fume phase identification results in terms of the anticorrosive coating type effect on the chemical composition of fume it can be stated that, as regards Zn and Zn - Fe coatings, the type of a coating does not significantly affect the phase composition of fume generated during arc weld brazing processes. Zinc, manganese and iron compounds making up the fume come from the base material and from the protective coating, whereas the filler metal is the source of copper, silicon and manganese phase compounds. The type of a coating affects the percentage content of individual phase components in fume generated during weld brazing. For instance, a ZnO content in fume during argon - shielded weld brazing amounted to 84,5 % and 90,6 % for the Zn and Zn - Fe coatings. In the case of the Zn coating, a copper oxide (CuO) content amounted to 5,8 %. CuO was not detected in the fume generated during weld brazing the Zn - Fe coating. In turn, a Cu content for the Zn coating amounted to 6,2 %, whereas for the Zn - Fe coating it was 6,1 %. The zinc-iron alloy coating was responsible for a greater ZnO content in fume if compared with a ZnO content determined in the fume during weld brazing the Zn coating. ZnO content in fume during weld brazing

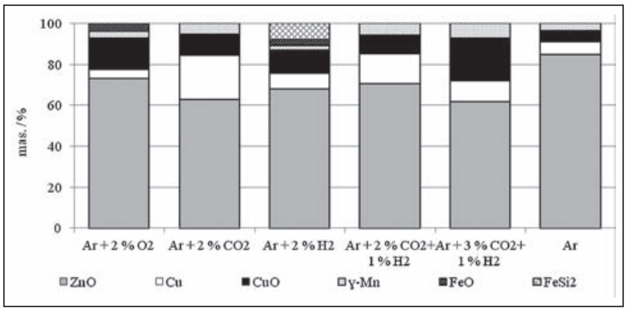

Figure 1 Phase analysis of fume during ColdArc weld brazing of DX54D Z100MBO sheet using various shielding gases

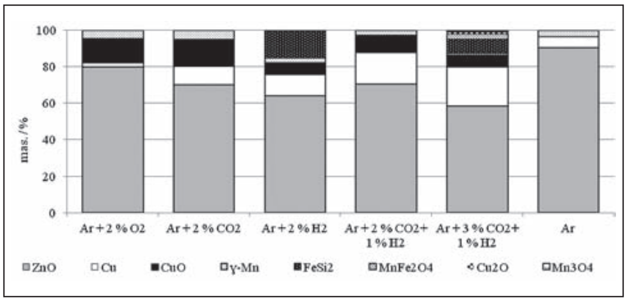

Figure 2 Phase analysis of fume during ColdArc weld brazing of DX54D ZF100RBO sheet using various shielding gases

sheets with the Zn - Fe coating was restricted within a 58,5 -90,6 % range. As regards joining sheets with the Zn coating, a ZnO content in fume was restricted within a 61,6 - 84,5 % range.

The research - related tests concerned with CMT (low - energy) and MIG / MAG weld brazing of DX54D Z100MBO grade steel sheet involved the phase identification and the quantitative phase analysis of fume depending on a shielding gas mixture used. The results for all phase components are presented in Figures 3 - 4. Figures 5 - 8 show the content of ZnO, CuO, Cu and g-Mn in fume generated during MIG / MAG, CMT and ColdArc weld brazing of DX54D Z100MBO grade sheet using various shielding gas mixtures.

The tests revealed that the composition of a shielding gas and a weld brazing method have a significant influence on the phase composition of fume and on amounts of individual components contained in fume.

The highest ZnO content in fume was connected with argon - shielded weld brazing and this phenomenon was observed for all the weld brazing methods investigated (Figure 5). The lowest ZnO content in fume was observed for MIG / MAG weld brazing shielded by a two - component Ar + H_2 mixture and by a three - component Ar + 3 % CO_2 + 1 % H_2 mixture. Also during CMT and ColdArc weld brazing, the lowest ZnO content was connected with a mixture of Ar + 3 % CO_2 + 1 % H_2 used as a shielding gas. The weld brazing method characterised by the highest ZnO content in fume was CMT. As regards ColdArc weld brazing, ZnO content in fume was lower by, on average, 10 %, if compared with the ZnO content found in the fume generated during CMT weld brazing (for all the shielding gases test-

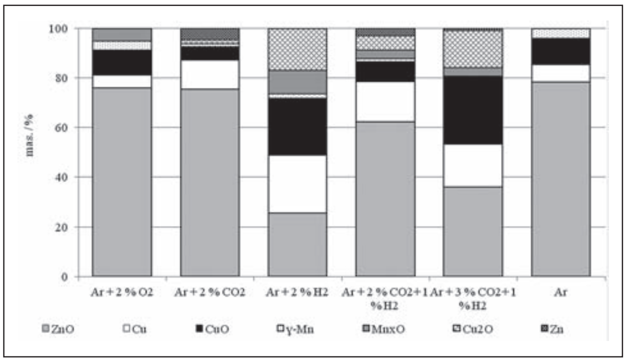

Figure 3 Phase analysis of fume during MIG / MAG weld brazing of DX54D Z100MBO sheet using various shielding gases

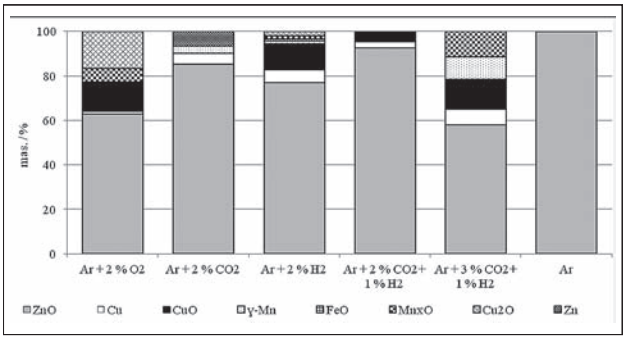

Figure 4 Phase analysis of fume during CMT weld brazing of DX54D Z100MBO sheet using various shielding gases

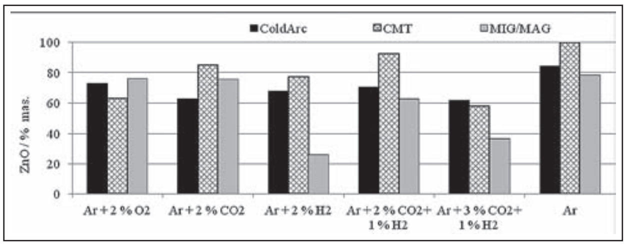

Figure 5 ZnO content in fume during arc weld brazing of Zn coated steel using various shielding gases

ed). ZnO content detected in fume during MIG / MAG weld brazing was lower by, on average, 20 %.

In terms of compounds coming from a filler metal such as metallic copper (Cu), cuprite (Cu_2O), i.e. copper(I) oxide and tenorite (CuO), i.e. copper(II) oxide, their contents in fume also depend on the chemical composition of a shielding gas and on a weld brazing method applied. The highest Cu content in fume was observed for MIG / MAG weld brazing using Ar+H_2 and three-component mixtures (Figure 6). During CMT weld brazing the highest Cu content in fume was connected with the use of Ar + 3 % CO_2 + 1 % H_2 used as a shielding gas, yet it should be emphasized that CMT weld brazing is characterised by a significantly lower Cu content in fume in comparison to MIG / MAG weld brazing. In relation to ColdArc weld brazing, the highest Cu content accompanied the use of two - component (Ar + 2 % CO_2) and three - component (Ar + 2 % CO_2 + 1 % H_2) gas mixtures. Copper(II) oxide (CuO) was found in fume for all the weld brazing methods and

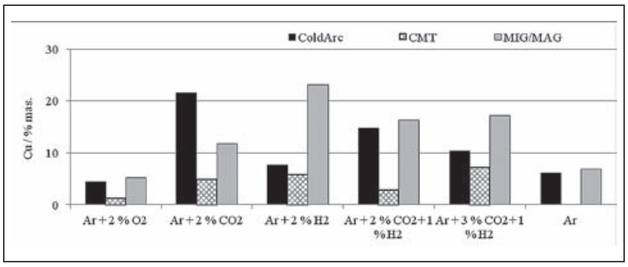

Figure 6 Cu content in fume during arc weld brazing of Zn coated steel using various shielding gases

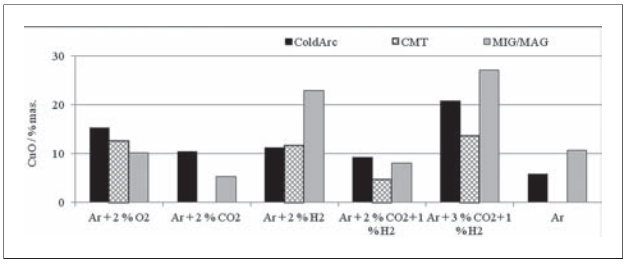

Figure 7 CuO content in fume during arc weld brazing of Zn coated steel using various shielding gases

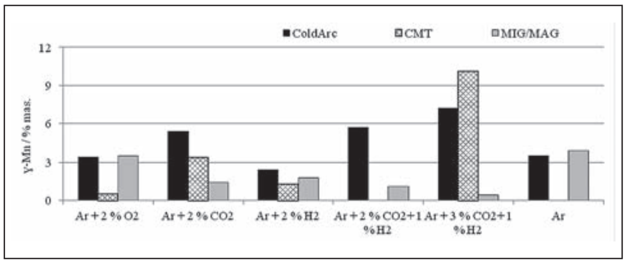

Figure 8 γ-Mn content in fume during arc weld brazing of Zn coated steel using various shielding gases

for most of the shielding gas mixtures used, except CMT weld brazing shielded by Ar and Ar + CO_2 (Figure 7). The highest CuO content in fume was detected for MIG / MAG weld brazing using Ar + 2 % H_2 and Ar + 3 % CO_2 + 1 % H_2 gas mixtures. Also in the case of ColdArc and CMT weld brazing, the highest CuO contents were connected with the use of Ar + 3 % CO_2 + 1 % H_2, Ar + 2 % O_2 and Ar + 2 % H_2 gas mixtures.

It was observed that weld brazing processes were accompanied by the presence of various manganese compounds in fume. Metallic manganese was present in fume generated during all the weld brazing methods tested (Figure 8). The content of g-Mn in fume was related to a shielding gas applied; the highest g-Mn content accompanied the use of three - component shielding gas mixtures.

CONCLUSION

From the work environment point of view, the presence of high contents of zinc, copper and manganese compounds in fume generated during weld brazing is of great importance [1]. Table 2 shows the influence of the shielding gases tested on a possibility of reducing Zn, Cu and Mn compounds present in fume during weld brazing processes.

Table 2 **Influence of a shielding gas on the reduction of Zn, Cu and Mn compound contents in fume**

Compound content	Shielding gas					
	Ar	Ar + 2 % O_2	Ar + 2 % CO_2	Ar + 2 % H_2	Ar + 2 % CO_2 + 1 % H_2	Ar + 3 % CO_2 + 1 % H_2
CMT method						
Zn	-	1	0	0	-	3
Cu	3	1	2	-	0	-
Mn	3	3	0	0	3	-
ColdArc method						
Zn	-	0	1	0	0	2
Cu	1	0	-	0	-	-
Mn	0	0	-	1	-	-
MIG / MAG method						
Zn	-	0	0	2	0	2
Cu	0	1	1	-	-	-
Mn	-	-	0	0	2	3
– - not satisfactory; 0 - neutral; 1 - medium; 2 - good; 3 - very good						

The use of “traditional” MIG / MAG weld brazing with Ar + 2 % H_2 and Ar + 3 % CO_2 + 1 % H_2 shielding gas mixtures has an advantageous effect on reducing the content of ZnO in fume. During CMT and ColdArc weld brazing, reduction of a Cu content in fume is connected with using argon or Ar + 2 % O_2 mixture as a shielding gas and in case of CuO content reduction in fume, it is necessary to use argon or Ar + 2 % CO_2 mixture.

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Note: The responsible translator for English language: Wojciech Cesarz, Cesarz Translation Office Gliwice, Poland