UDK 621.791:621.791.04
Professional article/Strokovni članek

ISSN 1580-2949
MTAEC9, 46(5)535(2012)

CONTENT OF Cr AND Cr (VI) IN A WELDING FUME BY DIFFERENT Cr CONTENT IN AN EXPERIMENTAL COATING OF A Cr-Ni RUTILE ELECTRODE

VSEBNOST Cr IN Cr (VI) V VARILNEM DIMU PRI RAZLIČNI VSEBNOSTI Cr V PLAŠČU RUTILNE ELEKTRODE Cr-Ni

Razija Begić[1], Monika Jenko[2], Matjaž Godec[2], Črtomir Donik[2]

[1]Faculty of Engineering, University of Bihać, Irfana Ljubijankića bb., 77000 Bihać, Bosnia and Herzegovina
[2]Institute of Metals and Technology, Lepi pot 11, Ljubljana, Slovenia
razijabegic@yahoo.co.uk

Prejem rokopisa – received: 2011-11-17; sprejem za objavo – accepted for publication: 2012-06-01

In the SMAW welding process welding fumes are generated, harmful to human health and the environment. A welding fume is a mixture of gaseous and solid phases, which are generated during most of the electric-arc-welding processes. This article presents the researches of the particles that constitute the solid-phase-welding fumes. The change in the chemical composition of an electrode and its components (the coating and the core) can affect the chemical composition of the particles in welding fumes. The largest amount of fumes, about 80 %, is generated from electrodes and, accordingly, the focus of research was the influence of the chemical composition of an electrode on the chemical composition of the welding-fume particles. This paper presents the research results obtained for the content of Cr and Cr (VI) oxide particles in welding fumes. The experimental work on six variants of commercial electrodes E 23 12 2 LR 12, a welding chamber collecting fume particles and a chemical analysis of the particles were applied according to the standard EN15011. The aim was to determine an experimental welding electrode that should generate the welding-fume particles with the lowest content of Cr and Cr (VI) oxide.

Keywords: health, welding fumes, particle, coated electrodes, Cr (VI)

Med varilnim procesom SMAW nastaja dim, ki je škodljiv za zdravje in okolje. Dim, ki nastaja pri večini varilnih procesov, je mešanica plinov in trdnih delcev. Ta članek opisuje preiskavo delcev, ki so trdni del dima, ki nastane pri varjenju. Spreminjanje sestave elektrode (stržena in obloge) vpliva na kemijsko sestavo trdnih delcev v dimu. Največji delež dima, okrog 80 %, izvira iz elektrode, zato je bila raziskava osredinjena na učinek kemijske sestave elektrode na kemijsko sestavo delcev v dimu. Ta članek navaja rezultate raziskav vsebnosti oksidnih delcev Cr in Cr (VI) v dimu pri varjenju. Eksperimentalno delo je bilo izvršeno s šestimi različnimi komercialnimi elektrodami E 23 12 2 LR 12. V varilni komori zbrani delci iz dima so bili analizirani skladno s standardom EN15011. Namen je bil ugotoviti eksperimentalno elektrodo, ki proizvaja med varjenjem delce z najmanjšo vsebnostjo Cr v Cr (VI)-oksidu.

Ključne besede: zdravje, varilni dim, delci, oplaščene elektrode, Cr (VI)

1 INTRODUCTION

No material of any source can be directly compared with the composition and structure of a welding vapour. Chromium is generated in flue gases of welding with coated high-alloyed Cr electrodes and it appears in several phases, of which the six-valent oxide of chromium, Cr (VI), is the most damaging. Epidemiological studies prove the Cr (VI) compounds to be occupational carcinogens. During the MAG stainless-steel welding much less Cr (VI) is generated than during SMAW. Cr (III) compounds are biologically inert because they do not enter the cell, while Cr (VI) causes cell mutation. Chromium has a low threshold limit value (TLV), which is 0.5 mg/m^3.[1]

2 EXPERIMENT

Experimental electrodes were made according to the experimental plan shown in **Table 1**, based on the changes in the chromium content in an electrode and its components (a wire[2] and an electrode coating), marked with labels A, B, C, D, E and F, representing six varieties of commercial electrodes E 23 12 2 LR 12.

Table 1: Change in the contents of Cr in an electrode and its components[4]

Tabela 1: Spreminjanje vsebnosti Cr v elektrodi in v plašču elektrode[4]

No	Electrode	Cr content in an electrode wire[2]	Cr content in an electrode coating	Mean Cr content in an electrode
1.	A	18.2 %	20.8 %	19.3 %
2.	E		22.8 %	20.1 %
3.	C		29.4 %	22.8 %
4.	B	19.6 %	18.1 %	19.0 %
5.	F		20.0 %	19.8 %
6.	D		27.4 %	22.7 %

For the tests related to emissions and their qualitative and quantitative chemical analyses it is necessary to have the appropriate equipment, which primarily consists of a collecting chamber, made for the purpose of this research according to the model in the standard EN15011[3]. The chemical composition of the welding-fume particles was obtained with the tests for six experimental electrodes, a

total of 18 probes. The current level was constant, $I = 95$ A, and the basic material was a low-carbon, unalloyed structural steel S235JRG2.

3 RESULTS

The content of chromium in the welding-fume particles is shown in **Table 2**, determined with the AAS method.

Table 2: Results of a chemical analysis of the Cr content in the fume particles[4]
Tabela 2: Rezultati kemijske analize vsebnosti Cr v delcih dima[4]

No	Electrode	Probe	Cr content in the welding-fume particles, %	
			Cr content	Cr mean value
1	A	A1	5.62	5.91
2		A2	6.00	
3		A3	6.10	
4	B	B1	5.33	5.09
5		B2	5.20	
6		B3	4.73	
7	C	C1	6.00	5.58
8		C2	5.84	
9		C3	4.90	
10	D	D1	5.05	5.18
11		D2	5.40	
12		D3	5.05	
13	E	E1	5.10	5.06
14		E2	4.95	
15		E3	5.10	
16	F	F1	5.30	5.05
17		F2	5.00	
18		F3	4.85	

SEM-EDS and XPS chemical analyses of fume particles were carried out at the Institute of Metal Materials and Technology, Ljubljana. As an addition to the analysis of Cr and Cr (VI) in welding fumes and particles, the performed chemical analyses also included the contents of Mo, Mn and Ni as the most influential alloying elements and other elements and compounds. The change in the content of Cr particles in welding fumes shown in **Figure 1** depends on the increase in the Cr content in the lining of an experimental electrode.

The functional dependence of the Cr content in welding fumes and the Cr content in the electrode coating in **Figure 1** corresponds to the exponential equation:

$$Cr_{ZD} = 5.05 + (1.74 \cdot 10^{-8})^{\frac{Cr_{coating}}{1.7}} \quad (1)$$

Reliability of the calculated functional dependence is relatively high with $R^2 = 0.98$.

A graphical representation of functional dependencies of the contents of Cr (VI) particles in welding fumes on the Cr content in electrodes and in electrode coatings is shown in **Figure 2**.

Figure 2 corresponds to the exponential equation:

$$Cr(VI)_{ZD} = 4.74 + (6.2 \cdot 10^{-7})^{\frac{Cr_{coating}}{2.16}} \quad (2)$$

The reliability of functional dependence is relatively high being $R^2 = 0.97$.

4 DISCUSSION

The test conditions for electrode A were different than for the other electrodes and for this reason electrode A was excluded from the further analysis. The shape of the curve in **Figure 1** shows that a 23–24 % addition of Cr to the electrode coating causes no significant increase in the Cr content in welding fumes. However, if this amount is increased the content of Cr particles in welding fumes has a much stronger growth trend. Similarly, from **Figure 2** it can be concluded that no significant increase in the content of Cr (VI) particles in welding

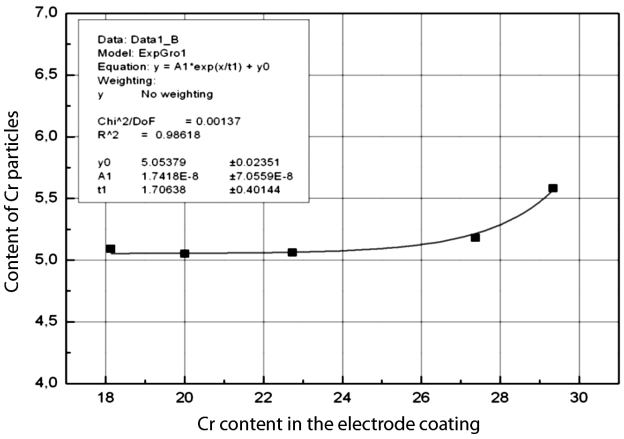

Figure 1: Content of Cr particles depending on the Cr content in the electrode coating[4]
Slika 1: Vsebnost Cr v delcih v odvisnosti od vsebnosti Cr v plašču elektrode[4]

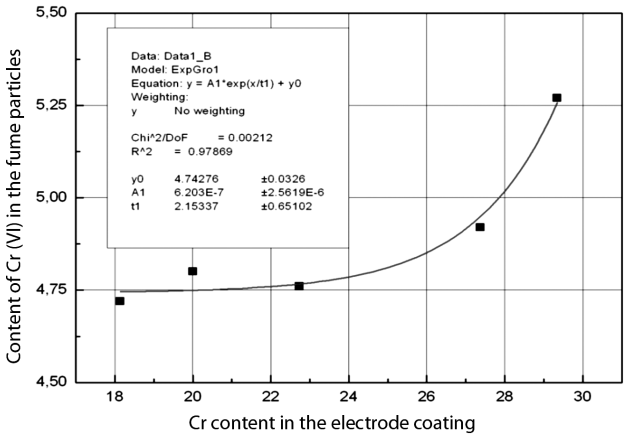

Figure 2: Content of Cr (VI) in the fume particles depending on the Cr content in the electrode coating[4]
Slika 2: Vsebnost Cr (VI) v delcih dima v odvisnosti od vsebnosti Cr v plašču elektrode[4]

fumes occurs due to a concentration of Cr in the electrodes above 24–25 % Cr.

5 CONCLUSION

The problems of welding fumes are becoming associated with harmful emissions that increasingly affect the protection of people and environment. Throughout the world we have seen an increased use of welding needed for joining the structures that are more and more being made of alloyed steel. Therefore, the production of the welding smoke is larger and the increasing use of the high-alloyed electrodes and the resulting chemical compositions of welding fumes are becoming more harmful. Any reduction of the harmful emissions to the atmosphere increases the protection of the people and environment. This paper explores this issue and the results obtained can be applied to the development of the electrodes for SMAW with a lower level of harmful emissions allowing a satisfactory quality of a weld. Two basic requirements needed for a SMAW process and for the coated electrodes are examined. After qualitative and quantitative analyses of the particles in the welding fumes a feedback loop can be introduced, based on the formation of solid particles, helping us to make decisions on the introduction of a new alloy coating on the electrodes that can lower the amount of harmful components in the welding-fume particles.[4]

6 REFERENCES

[1] V. E. Spiegel-Ciobanu, Von "Schweißrauche" zu "Schweißtechnische Arbeiten", Die neuen technischen Regeln für Gefahrstoffe, Hannover, TRGS 528 TÜ Bd.50, 2009, Nr. 9

[2] Rodacciai, Certificato di collaudo, Italia, May 2008

[3] EN ISO 15011-1, Health and safety in welding and allied processes-Laboratory method for sampling fume and gases generated by arc welding-Part 1: Determination of emission rate and sampling for analysis of particulate fume, April 2002

[4] R. Begić, Doctoral dissertation, Exploring optimal technological composition of electrode coatings in terms of minimizing welding fumes, September 2011, Faculty of Engineering, University of Bihać