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WELDING FUME PRODUCTION AS A FUNCTION OF ELECTRODE COATING COMPOSITION

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ABSTRACT
All welding parameters are optimised to achieve satisfactory weld joint quality. Electrode coating at MMAW (metal manual arc welding) procedure has several functions: electric, metalurgical and protective function. During MMAW welding significant amount of welding fume is generated. Chemical structure of welding fume depends of welding consuments engaged in process. Many components of welding fume are hazardous for welders' health and enviroment. Quantity and chemical composition of welding fume are determined by european standards. Changing coating structure affects on welding fume chemical composition. Electrode coating structure differs by manufacturer.
Keywords: coated electrode, welding fume, chemical analysis

1. INTRODUCTION
Welding fumes are defined as toxic metal fumes generated during welding [1]. Welding fume components generated during welding can be health hazardous if inhaled or swallowed. Nowadays ecological demands are stricter and they are implemented as legislative norm regarding protection of human health at work. Regarding toxicity it is necessary to determine quantity and chemical structure of welding fumes. Chemical structure of welding fume is determined by basic and additional welding material, welding current, shielded gases and environment gases. It is estimated that present production of additional welding material in world is around million tones per a year [2]. If we know that 0,5 percent of addittional material total mass is welding fume then 5000 tones of welding fume is generated per a year [3]. More than 90% percent of total fume generates from electrode melting. Elektode coating is significant source of welding fume.

2. HAZARDOUS COMPONENTS OF WELDING FUME DURING MMAW WELDING
Welding fume generated during REL coated electrode welding is colloid suspension of gaseous and dispersive phase. Dispersive phase represents small particles of which ones sized 5 [μm] are most dangerous. These particles weight is ~ 30 % of total particle mass in welding fume. Largely medical examinations on effects of chemical compounds and compounds on human organism showed many hazardous compounds in welding fumes. The most harmful compound of welding fume is Cr (VI) which is carcinogenic as well as Ni, Cd, Co, Mn which is neurotoxin, Zn, affects immune system, Cu causes breathing disorder, Pb toxic and harmful for kidneys, Al causes fibrosis, Ba is hazardous for

nerve system and causes balance and salt disorder [4, 5]. This research results bring to enroling standards which determines total allowed quantity of welding fumes and maximum content of particular components in welding fume. Beside national regulations, EWF (European Welding Federation) gives directions for manufacturers of welding constructions Doc. EWF 615–02 and way of approaching and managing of surroundings with regard to regulation EN 14001.

3. MMAW WELDING ELECTRODES

MMAW welding is performed with coated electrode. If we want to change welding fume structure we need to change electrode coating structure. Non - metal electrode coating has complex structure and it represents mixture of organic and mineral supstances. More than 90% percent of welding fume during MMAW welding generates by combustion of electrode coating elements.

3.1. Electrode coating structure for MMAW welding

Electrode coating has functions as follows [6]:

1. Conductivity of the arc plasma is improved by
   a) facilitated ignition
   b) increased arc stability
2. Forming of slag, in order to
   a) influence the size of the metal droplet
   b) shield the transferring droplet and the weld pool (molten metal) from the atmosphere
   c) form the solidifying weld bead
3. Development of a gas shielding atmosphere consisting of
   a) organic components
   b) carbonates $CaCO_3$
4. Desoxidation and alloying of the weld metal
5.Additional input of filler material in the form of metallic particles (high-recovery electrode).

Constituents of electrode coatings for MMAW, and its influence on welding characteristics are given in Table 1. Electrode coating constituents data differs dependigly on manufacturer and they are not given in standard manufacturer program catalogues.

Table 1. Influence of the coating constituents on welding characteristics [6]

Coating raw material	Effect on the welding characteristics
Quartz SiO_2	To raise current-carrying capacity
Rutile TiO_2	To increase sla viscosity, good re-striking
Magnetite Fe_3O_4	To refine transfer of droplets through the arc
Calcareous spar $CaCO_3$	To reduce arc voltage, shielding gas emitter and slag formation
Fluorspar CaF_2	To increase slag viscosity of basic electrodes, decrease ionization
Calcareous fluorspar K_2O Al_2O_3 $6SiO_2$	Easy to ionize, to improve arc stability
Ferro manganese/ ferro sillicon	Deoxidant
Cellulose	Shielding gas emitter
Kaolin Al_2O_3 $2SiO_2$ $2H_2O$	Lubricant
Potassium water glass K_2 SiO_3/Na_2 SiO3	Bonding agent

4. WELDING FUME CHEMICAL COMPOSITION

Results of an american research on chemical analysis of welding fume particles during MMAW are given in table 2 [7]. Low alloy steels A-36, HY-100, HSLA-100 were used, and welding was performed with E 11018-M electrode. This table shows percentage of 18 chemical components in total sample.

Table 2. Chemical composition particulate welding fume

Base metal	**A - 36**	**HY- 100**	**HSLA - 100**
ELECTRODE	**HY 11018 - M**	**HY 11018 - M**	**HY 11018 - M**
Chemical composition of MMAW fume (weight percent %)			
Cr (VI)	<0.1	<0.1	<0.1
Al	0.3	0.2	0.3
Ti	1.0	1.1	1.1
Si	2.8	3.0	2.9
Fe	20.3	18.3	18.2
Ca	13.8	14.1	14.4
Mn	7.5	7.3	7.6
K	7.2	7.9	7.7
Ba	<0.2	<0.2	<0.2
Ni	<0.2	<0.2	<0.2
Cr	<0.2	<0.2	<0.2
Mo	<0.2	<0.2	<0.2
Nb	<0.2	<0.2	<0.2
V	<0.2	<0.2	<0.2
Cu	<0.2	<0.2	<0.2
Na	8.9	9.1	9.1
Li	<0.2	<0.2	<0.2
P	18.1	20.9	19.2

Table 3 gives chemical analysis of welding fume particles generated by EL 27 R and EL E 61B electrodes Ø 3.25 [mm]. These electrodes are manufactured in ELVACO Bijeljina. Analysis were performed by „Liverpol Regional Office“ UK organisation. This table shows percentage of constituents in total welding fume particles for 10 chemical components.

Table 3. Analysis of chemical structure of welding fume (Liverpol)

ELECTRODE	**EL E 27 R**	**EL E 61 B**
Chemical composition of MMAW fume (weight percent %)		
Fe	5.5	3.4
Mn	6.4	4.8
F	-	16.2
Zn	0.010	0.01
Ni	0.002	0.02
Cu	0.044	0.03
Cr	0.06	0.02
Mo	0.001	0.01
Co	-	-
Pb	0.002	0.01

Table 4 gives chemical analysis results of electrodes like in table 3. This analysis were performed in Institute „ Kemal Kapetanović“ in Zenica, and it is shown percentage of 17 chemical components in total welding fume particles analysed.

Table 4. Chemical composition and quantities of chemical components in welding fume particles.

No	Chemical component	Chemical component [%]					
		Electrode and sample					
		EL E 27 R			EL E 61 B		
		R1	R2	R3	B1	B2	B3
01.	**Ca**	0,18	0,07	0,03	9,9	9,6	10,3
02.	**Fe**	23,5	24,4	29,5	16,7	14,5	13,1
03.	**Cu**	0,22	0,10	0,10	0,030	0,021	0,018
04.	**Cr**	0,031	0,074	0,039	0,020	0,013	0,012
05.	**Al**	0,40	0,42	0,17	0,51	0,62	0,56
06.	**Pb**	0,094	0,054	0,047	0,034	0,034	0,032
07.	**Cd**	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
08.	**Ni**	0,008	0,008	0,008	0,001	0,006	0,006
09.	**Mn**	5,31	4,65	5,22	4,30	3,69	3,78
10.	**Zn**	0,49	0,15	0,19	0,052	0,073	0,073
11.	**Co**	0,009	0,011	0,010	0,052	0,008	0,009
12.	**Na**	5,41	4,60	7,72	3,80	2,75	3,76
13.	**Mo**	0,023	0,008	0,022	0,028	0,030	0,027
14.	**Mg**	0,07	0,06	0,05	0,29	0,28	0,23
15.	**Ti**	4,35	3,36	1,94	0,63	0,64	0,65
16.	**Si**	6,34	-	-	2,62	-	-
17.	**F**	< 0,1	-	-	19,2	-	-

5. CONCLUSION

Typ and chemical structure of coating together with chemical structure of base material determines chemical composition of welding fume. By changing constituents of electrode coating we can reduce or increase quantites of welding fumes hazardous components. Precondition for experimenting with constituents of electrode coating is posibilitie of collecting welding fume particles. For that purpose welding fume chamber was built by EN ISO 15011-1: 2002.[8], which is placed in „Engineering faculty“ in Mostar. Welding fume particles for above mentioned electrodes were collected. Chemical analysis results performed in Institute „Kemal Kapetanović“ Zenica are given in Table 4. Six experimets were performed 3 for each electrode. To compare results of chemical analysis sampling should be performed under same conditions which was not case for these experimets. After removing welding fume flaws we will proceed to next experimental phase, making labaratorian electrodes with variety of coating constituents.

6. LITERATURE

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