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Theoretical and Experimental Contributions on Environmental Pollution through the Process of Welding Flux Layer (SAF)

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Abstract

In the present study it is presented a research conducted to highlight the types of harmful substances resulting from the welding using the welding flux layer (SAF) and the coefficient values of total pollution and its variation depending on the parameters of welding regime.

Key words: *environment, pollution, welding, gas, microparticles*

Introduction

It can be said with certainty that no area of our economy, in which the welding procedures and not to be found applicable, since the achievement microchips to space shuttle and intercontinental missiles from submarines to the largest and most interesting works of art made in grid construction (bridges and highways suspended installations for metros and large waterways, supermarkets and exhibition halls, etc.).

Most welding processes, the operating mode, receiving the materials used and the technological equipment with which it is made, has a major impact on the environment and pollution is not negligible[1].

Theoretical Research

The main phenomenon that occurs in the arc column and that is directly related to pollution of the environment process is the phenomenon of dissociation of gas, which is going different temperatures (Table 1).

Dissociation of diatomic gases is made by a general reaction of the form:

$$X_2 = 2X \tag{1}$$

where: X indicates any gas species.

Table 1. Temperatures for 90% dissociation of gas in the arc column

Gas	Gas dissociation temperature (K)
CO_2	3800
O_2	5100
H_2	4575
N_2	8300

It goes on to consider a gas welding which consists of two components, eg an inert component (argon or helium) and active one. When the value of the dissociation fraction is close to one, the partial pressure of species X, p_x gas phase is equal to:

$$p_x = \frac{n_x}{n_I + n_x} p_{tot} \tag{2}$$

where: n_I and n_x are the total numbers of moles of components I (inert gas) and X, such as gas welding, total pressure p_{tot} [(the atmosphere).

From equation (1) that 2 moles of X is formed from each mole of X2, which is dissociated. Therefore equation (2) can be written as:

$$p_x = \frac{2n_x}{n_I + 2n_{X_2}} p_{tot} \tag{3}$$

where n_{X_2} is the total number of moles of component X_2, which was currently in protective gas.

If n_{X_2} and n_I are commensurate with the volume concentrations of gas components such protective gas, equation (3) becomes:

$$p_X = \frac{2(vol\%X_2)}{vol\%I + 2(bol\%\ X_2)} p_{tot} \tag{4}$$

Having $vol\%\ I = (100 - vol\% X_2)$ *and* $p_{tot} = 1atm$ we have obtained the following expression for p_X:

$$p_X = \frac{2(vol\%X_2)}{100 + vol\%X_2} \tag{5}$$

Similarly, if X_2 is replaced by another type YX_2 gas component, we obtain:

$$YX_2 = X + YX \tag{6}$$

and

$$p_x = \frac{vol\%YX_2}{100 + vol\%YX_2} \tag{7}$$

It follows that the partial pressure of components dissociated X increases monotonously with increasing concentrations of X_2 and YX_2 the protective gas. Partial pressure p_x is also dependent on the nature of the active gas component in the arc column. This means that, for example, oxidation capacity of CO_2 is only half that of the O_2, when comparison is made on the basis of the gas concentrations equal protection.

Equations (5) and (6) are important in explaining the emergence of form components CO_x, SOx, NOx, etc. CH_x. Responsible for polluting the atmosphere, due to welding process

Experiments conducted and determinations have shown that especially the burning shell of electrodes in electric arc, or streams used in arc welding bath or place a series of reactions, with formation following gases [2].

- formation of CO, according to the following reactions:

$$6Fe_2O_3 + 2C = 4Fe_3O_4 + 2CO \uparrow \quad (8)$$

$$2Fe_3O_4 + 2C = 6FeO + 2CO \uparrow \quad (9)$$

$$2FeO + 2C = 2Fe + 2CO \uparrow \quad (10)$$

- formation of CO2, both the arc and molten metal bath formed from melting material addition and material basis, as follows:

$$C + O_2 = CO_2 \uparrow \quad (11)$$

$$2H_2O + C = H_2 \uparrow + CO_2 \uparrow \quad (12)$$

$$6Fe_2O_3 + 2CO = 4Fe_3O_4 + CO_2 \uparrow \quad (13)$$

$$2Fe_3O_4 + 2CO = 6FeO + CO_2 \uparrow \quad (14)$$

- formation of NO_x, especially in the formation of welding bath melt all components, as follows:

$$N_2 + O = N + NO \uparrow \quad (15)$$

$$NCO + O = CO \uparrow + NO \uparrow \quad (16)$$

$$O_2 + N = O \uparrow + NO \uparrow \quad (17)$$

- formation of SO_x sulfur compounds to achieve welding bath melt flow wrappers or used:

$$S + O_2 = O \uparrow + SO \uparrow \quad (18)$$

$$SO + O_2 = O \uparrow + SO_2 \uparrow \quad (19)$$

$$SO_2 + O_2 = O \uparrow + SO_3 \uparrow \quad (20)$$

- micropowders formation or metal powders, as follows:

$$\frac{2}{3} Fe_2O_3 + 2CO = \frac{4}{3} Fe + 2CO_2 \uparrow \quad (21)$$

$$\frac{1}{2}Fe_3O_4 + 2CO = \frac{3}{2}Fe + 2CO_2 \uparrow \tag{22}$$

$$2FeO + 2CO = 2Fe + 2CO_2 \uparrow \tag{23}$$

Calculation Relations Used to Determine the Quantities of Pollutants

Environmental impact assessment of the welding process is made in determining the amount of substances removed from the atmosphere or on land and affecting different environment. In the measurements to directly determine the following parameters: gas temperature, expressed as a C, CO concentration in ppm, NO concentration in ppm, SO_2 concentration in ppm, O_2 concentration in %.

CO_2 concentration expressed in% volume can be obtained directly but can be calculated. By the analyzer with the concentration of O_2 and CO_2 are determined maximum value characteristic for each type of fuel (eg, CO_2) using the relationship:

$$CO_2 = CO_{2_{max}}\left(1 - \frac{O_{2_{meas}}[\%]}{20.95\%}\right) \tag{24}$$

The device allows direct determination of NO concentration in ppm.

Along with NO, gases resulting from burning different fuels contain relatively high levels of NO_x (especially NO_2).

Determination of NO_x is carried out using a relation of the form: [3],[4].

$$NO_x[ppm] = \frac{NO[ppm]}{0.95} \tag{25}$$

Where, the analyzer is equipped with sensor for the determination of NO_2, NO_x amount is determined by the following relationship:

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$$NO_x[ppm] = NO[ppm] + NO_2[ppm] \tag{26}$$

The device allows direct determination of CO concentration in ppm.

To make calculation of CO in the gas resulting value independently of excess air, use the following relationship..

$$CO_{undil} = CO \cdot \lambda \tag{27}$$

where: CO is the concentration of CO; λ - excess air.

GA-40 plus can also calculate the mass, expressed in [mg/m3] based on gas concentrations expressed in [ppm], depending on the weight equally pressure and temperature.

GA-40 analyzer also shows different values expressed in [mg/m3], called "absolute mass concentration" and "mass concentration relative to oxygen, thus:

- determine the mass of CO, with the relationship of the form:

$$CO\left[mg/m^3\right]=CO\left[ppm\right]\cdot A_{CO} \tag{28}$$

where: CO [mg/m^3] is the absolute mass of CO (standard conditions); CO [ppm] - absolute concentration (of measurement); A_{CO} - - correction factor whose values are given in table 2.

Table 2. The values of correction factor at standard conditions 1000hPa, 0 ^{0}C

Gas	$A\left[\frac{mg}{m^3\cdot ppm}\right]$
CO	1.250
NO	1.340
SO_2	2.860
NO_2, NO_x	2.056
H_2S	1.520
H_2	0.089

- determine the mass of NO_x, NO_x, mass is calculated directly by taking into account the analyzer NO_2 factor.

- determine the mass of CO relative concentration based on concentration O in gases. Relationship is made using a form:

$$CO_{rel}\left[mg/m^3\right]=\frac{20.95\%-O_{2ref}}{20.95\%-O_{2meas}}\cdot CO\left[mg/m^3\right] \tag{29}$$

where: CO_{rel} is the mass of CO relative to O_2, expressed in mg/m^3; O_{2ref} - benchmarking the O_2% vol; O - measured value of O% vol.; 20.95% - a value in the pure air, CO -- measured amount of CO in the flue gas in mg/m^3.

Pollution coefficient Cp can establish a relationship based on calculation of the form:[4]

$$C_p=\frac{Gt_{ef}}{G_{ue}} \tag{30}$$

where: G_{tef} is the total weight of material added, in g; G_{ue} - useful weight calculated by the relationship:

$$G_{ue}=Gt_{ef}-G_p \tag{31}$$

where: G_p is the mass of contaminants, air or soil calculated with the relationship.

$$G_p=G_{paer}+G_{ps} \tag{32}$$

where: G_{paer} is the weight of substances that pollute the air, G_{ps} - weight of substances that pollute the soil.

Weight substances that pollute the air is calculated with relation:

$$G_{paer}=G_m+G_{H_2}+G_{CO}+G_{NO}+G_{NO_2}+G_{H_2S}+G_{an} \tag{33}$$

where: G_m refers to microparticles with smaller weight of 5µm, which remain in the air or are deposited after a long time a certain extent; G_{CO} - the weight of CO emitted into the atmosphere; G_{NO} - NO weight emitted into the atmosphere; G_{NO2} - the weight of NO_2 issued on atmosphere;

G_{H2S} - H_2S weight emitted into the atmosphere; G_{H2} - H_2 weight emitted into the atmosphere, G_{an}-weight of other substances collected.

Weight substances that pollute the soil G_{PS} calculates the relationship

$$G_{ps} = G_{pp} + G_{mp} \tag{34}$$

where: G_{pp} is the mass of particles that reach the ground, G_{mp} - microparticles weight remaining in the atmosphere and deposited gradually;

If gas welding protective environment for determining the pollution coefficient C_p will use the relationship below, all other relationships are generally valid.

$$C_p = \frac{Gt_{ef}}{G_{ue}} \tag{35}$$

Experimental Results

Gas values resulting from the submission cords and taken "online" during the deposition by welding using manual welding process with coated electrodes are presented in Tables 3 and 4. Environmental impact assessment process for SAW after the material balance equation. Material balance equation for the process has the form:

$$m_s = m_{md} + m_{pa} + m_{ps} + m_{pnd} \tag{36}$$

where: m_s is the mass of wire, used in welding; m_{md} - mass of metal or alloy deposited in the weld seam and is determined by weighing, using special processes; m_{pa} - mass loss in the atmosphere and includes all substances released in the welding, and remain in the atmosphere, determining the relationship is:[5],[6].

$$m_{pa} = m_{CO} + m_{CO_2} + m_{NO} + m_{NO_2} + m_{NOx} + m_{SO_2} + m_{H_2S} + m_{H_2} + m_{agn} \tag{37}$$

where: m_{co} is the mass of CO, freeing the air, m_{CO2} - CO_2 mass, freeing the air, m_{NO} - NO mass, releases into the atmosphere; m_{NO2} - the mass of NO_2, relaxed in atmosphere; m_{NOx}- mass of other nitrogen oxides released into the atmosphere; m_{SO2} - the mass of SO_2, discharged into the atmosphere; m_{H2S} - the mass of H_2S, the atmosphere relaxed; m_{H2} - H_2 mass, releases into the atmosphere, m_{agn} - the mass of other gases released into the atmosphere undetectable and can be calculated according to the nature of the process, wire and base material, the relationship:

$$m_{agn} = (0{,}01...0{,}05)\cdot m_{CO} \tag{38}$$

and, m_{PS} - weight loss on land and includes all substances deposited on the ground after process welding, which is calculated by the relationship:

$$m_{ps} = m_{mp} + m_{ss} + m_{pg} \tag{39}$$

where m_{mp} - microparticles mass and particles that appear after process welding and filed on the ground, m_{ss} - mass metal splashes that leap of solder bath and is deposited on the ground, m_{pg} - weight loss in slag, which is determined by weighing.

Table 3. Extract with the actual weight values and regimes of welding parameters used in the experiments for SAW

No.	Wire and flux type	GVM [g]	GF [g]	Parameters					M_{placa} [g]	M+CS [g]	M+DP [g]	M_{zgura} [g]	CDF [g]
				Is [A]	Ua [V]	t [s]	Vs [cm/s]	El [kJ/cm]					
1	S1+SA Z1 65 AC	482	337.4	400	26	60	1.2	6.93	16000	16819.4	16629.4	190	147.4
2		482	482	500	30	60	1.2	10	16000	16964	16667	297	185
3		482	626.6	600	34	60	1.2	13.6	16000	17108.6	16713.6	395	231.6
4	S1+SF MS 1 88 AC	482	337.4	400	26	60	1.2	6.93	16000	16819.4	16634.4	185	152.4
5		482	482	500	30	60	1.2	10	16000	16964	16744	220	262
6		482	626.6	600	34	60	1.2	13.6	16000	17108.6	16721.6	387	239.6
7	S2+SA Z1 65 AC	482	337.4	400	26	60	1.2	6.93	16000	16819.4	16632.4	187	150.4
8		482	482	500	30	60	1.2	10	16000	16964	16688	276	206
9		482	626.6	600	34	60	1.2	13.6	16000	17108.6	16729.6	379	247.6
10	S2+ SF MS 1 88 AC	482	337.4	400	26	60	1.2	6.93	16000	16819.4	16599.4	220	117.4
11		482	482	500	30	60	1.2	10	16000	16964	16651	313	169
12		482	626.6	600	34	60	1.2	13.6	16000	17108.6	16702.6	406	220.6
13	S3+SA Z1 65 AC	482	337.4	400	26	60	1.2	6.93	16000	16819.4	16626.4	193	144.4
14		482	482	500	30	60	1.2	10	16000	16964	16661	303	179
15		482	626.6	600	34	60	1.2	13.6	16000	17108.6	16710.6	398	228.6
16	S3+SF MS 1 88 AC	482	337.4	400	26	60	1.2	6.93	16000	16819.4	16614.4	205	132.4
17		482	482	500	30	60	1.2	10	16000	16964	16767	197	285
18		482	626.6	600	34	60	1.2	13.6	16000	17108.6	16717.6	391	235.6
19	S3Si+SA Z1 65 AC	482	337.4	400	26	60	1.2	6.93	16000	16819.4	16606.4	213	124.4
20		482	482	500	30	60	1.2	10	16000	16964	16662	302	180
21		482	626.6	600	34	60	1.2	13.6	16000	17108.6	16707.6	401	225.6
22	S3Si+SF MS 1 88 AC	482	337.4	400	26	60	1.2	6.93	16000	16819.4	16636.4	183	154.4
23		482	482	500	30	60	1.2	10	16000	16964	16669	295	187
24		482	626.6	600	34	60	1.2	13.6	16000	17108.6	16721.6	387	239.6
25	S4+SA Z1 65 AC	482	337.4	400	26	60	1.2	6.93	16000	16819.4	16641.4	178	159.4
26		482	482	500	30	60	1.2	10	16000	16964	16675	289	193
27		482	626.6	600	34	60	1.2	13.6	16000	17108.6	16726.6	382	244.6

28	S4+SF MS 1 88 AC	482	337.4	400	26	60	1.2	6.93	16000	16819.4	16643.4	176	161.4
29		482	482	500	30	60	1.2	10	16000	16964	16667	297	185
30		482	626.6	600	34	60	1.2	13.6	16000	17108.6	16713.6	395	231.6

Table 4. Extract with the resulting gas values and coefficients of pollution for SAW

No.	Wire and flux type	CO [ppm]	NO [ppm]	SO_2 [ppm]	H_2S [ppm]	H_2 [ppm]	Gpaer [g]	Gpp [g]	Gps [g]	Gp [g]	Gue [g]	Cp
1	S1+ SA Z1 65 AC	127	76	3	2	22	3.223964862	190	190	193.224	626.176035	1.30858
2		130	89	4	4	29	3.634862345	297	297	300.635	663.365138	1.4532
3		183	93	3	5	34	4.330227315	395	395	399.33	709.269773	1.56302
4	S1+ SF MS 1 88 AC	99	88	0	3	16	3.097534867	185	185	188.098	631.302465	1.29795
5		103	92	2	6	27	3.392538188	220	220	223.393	740.607462	1.30163
6		134	99	3	7	37	3.993080663	387	387	390.993	717.606919	1.54486
7	S2+ SA Z1 65 AC	134	57	1	0	14	2.770924048	187	187	189.771	629.629076	1.3014
8		176	87	2	0	27	3.993080663	276	276	279.993	684.006919	1.40934
9		185	95	4	0	37	4.382906479	379	379	383.383	725.217094	1.52865
10	S2+ SF MS 1 88 AC	166	49	0	1	19	2.992176539	220	220	222.992	596.407823	1.37389
11		190	76	0	3	22	3.866650668	313	313	316.867	647.133349	1.48965
12		199	87	0	5	33	4.330227315	406	406	410.33	698.269773	1.58764
13	S3+ SA Z1 65 AC	99	56	2	2	19	2.465384895	193	193	195.465	623.934615	1.31328
14		136	69	1	3	25	3.192357363	303	303	306.192	657.807643	1.46547
15		156	84	4	4	34	3.856114835	398	398	401.856	706.743885	1.5686
16	S3+ SF MS 1 88 AC	125	83	0	0	20	3.276644026	205	205	208.277	611.123356	1.34081
17		156	88	1	0	20	3.719149008	197	197	200.719	763.280851	1.26297
18		187	97	0	0	31	4.340763148	391	391	395.341	713.259237	1.55427
19	S3Si+ SA Z1 65 AC	113	76	0	2	33	3.160749865	213	213	216.161	603.23925	1.35833
20		145	88	0	2	37	3.792899838	302	302	305.793	658.2071	1.46458
21		176	94	0	2	40	4.27754815	401	401	405.278	703.322452	1.57623
22	S3Si+ SF MS 1 88 AC	125	63	0	4	41	3.118606533	183	183	186.119	633.281393	1.2939
23		167	75	0	5	45	3.866650668	295	295	298.867	665.133349	1.44933
24		190	86	0	7	49	4.403978145	387	387	391.404	717.196022	1.54574
25	S4+ SA Z1 65 AC	88	91	0	0	25	3.1080707	178	178	181.108	638.291929	1.28374
26		103	99	0	0	29	3.476824851	289	289	292.477	671.523175	1.43554
27		119	102	0	0	32	3.740220673	382	382	385.74	722.859779	1.53363
28	S4+ SF MS 1 88 AC	101	79	0	4	41	3.202893196	176	176	179.203	640.197107	1.27992
29		131	83	0	7	47	3.698077342	297	297	300.698	663.301923	1.45334
30		157	98	0	9	59	4.435585644	395	395	399.436	709.164414	1.56325

In relation (5.2) and m_{pnd} appears that the mass of other undetectable substances, which closed balance equation which can be calculated by the relationship:

$$m_{pnd} = (0,1...0,2)\cdot(m_{pa} + m_{ps}) \tag{40}$$

the nature of the added materials used, basic materials and type of welding process.

Using the above relations and experimental results obtained (Table 3 and tab. 4) have established the following: [7]

- the biggest pollution factor C_{pmax} = 1.587, was obtained when used the next parameters: Is = 600A, Ua = 34V, lc = 72cm, t = 60s, vs = 1.2 cm/s, El = 13.6 kJ/cm, S2 wire type and SFMS188AC flux, and wire diameter was DVM = 4 mm;

- the lowest coefficient of pollution C_{pmin}= 1.262, was obtained when used the next parameters: Is = 500A, Ua = 30V, lc = 72cm, t = 60s, vs = 1.2 cm/s, El = 10 kJ/cm, S3 wire type and SFMS188AC flux, and wire diameter was DVM = 4 mm;

- the highest concentration of carbon monoxide CO_{max} = 199ppm, was obtained following the use of welding regime: Is = 600A, Ua = 34V, lc = 72 cm, t = 60s, vs = 1,2 cm/s , El = 13,6 kJ/cm, S2 wire type and SFMS188AC flux, and wire diameter was DVM = 4 mm;

- the smallest concentration of carbon monoxide CO_{min}=88 ppm, was obtained when used the next parameters: Is = 400A, Ua = 26V, lc = 72 cm, t = 60s, vs = 1.2 cm/s, El = 6.93 kJ/cm, S4 wire type and SAZ165AC flux, and wire diameter was DVM = 4 mm;

- the largest concentration of nitrogen oxide NO_{max} = 102 ppm, was obtained when used the next parameters: Is = 600A, Ua = 34V, lc = 72 cm, t = 60s, vs = 1.2 cm/s, El = 13.6 kJ / cm, S4 wire type and SAZ165AC flux, and wire diameter was DVM = 4 mm;

Dependence between G_{ue} (useful weight) and the intensity of the welding current Is is indicated in figure 3 for each experiment conducted, for SAW.

The dependence between G_{paer} (weight of the substances that pollute the air) and the intensity of the welding current is indicated in figure 4 for each conducted experiment, for SMAW.[8],[9],[10].

Mean gas resulting from SAW welding process are shown in figure 1…5.

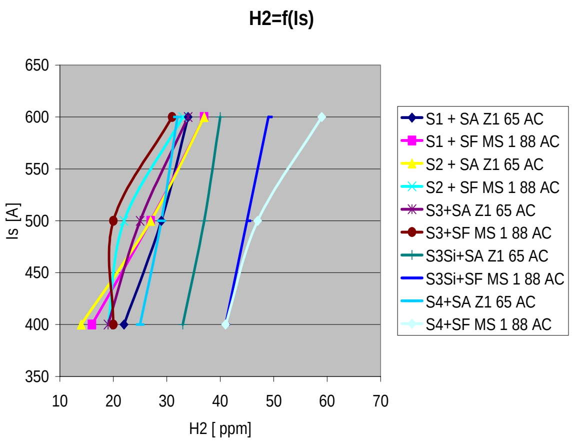

Fig. 1. Variation of the average values H_2

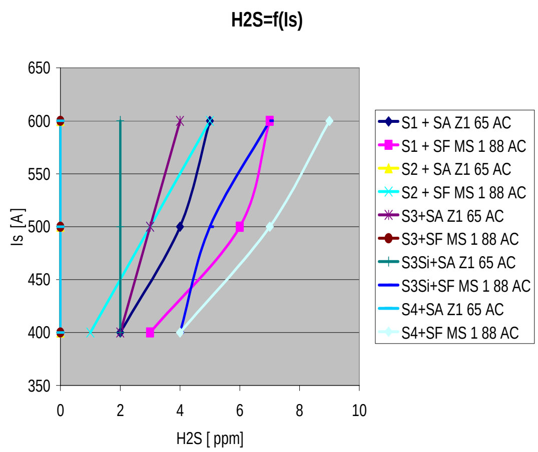

Fig. 2. Variation of the average values H_2S

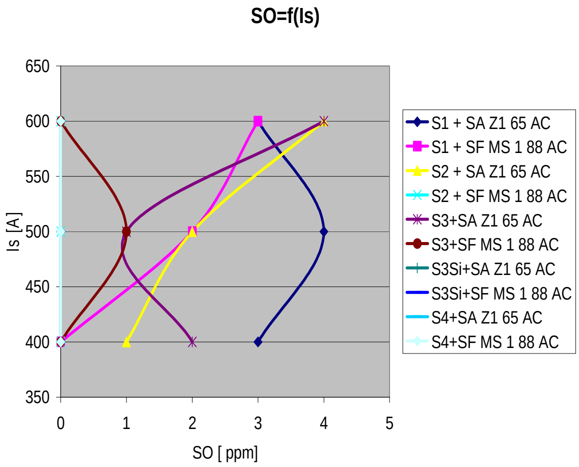

Fig. 3. Variation of the average values SO

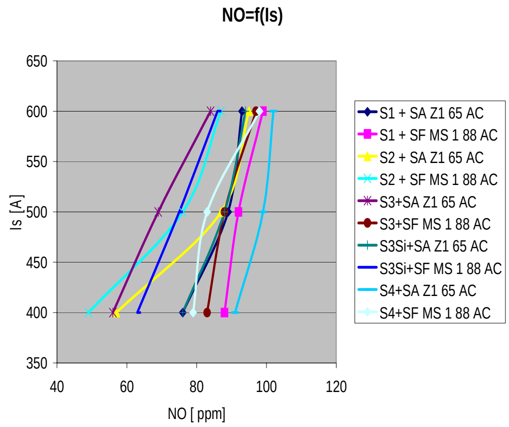

Fig. 4. Variation of the average values NO

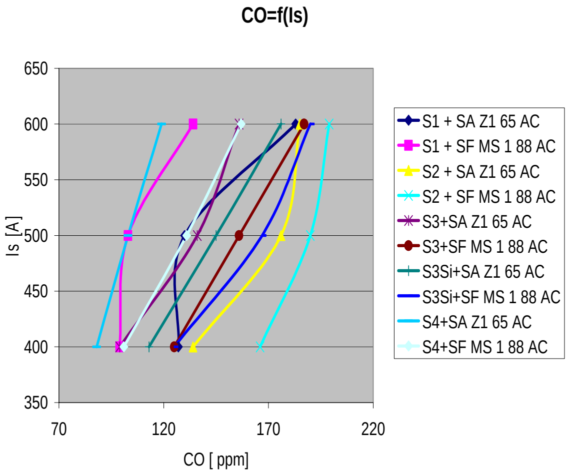

Fig. 5. Variation of the average values CO

Dependence between G_{ue} and the linear energy *El* is indicated in figure 6 for each experiment conducted, for SAW.

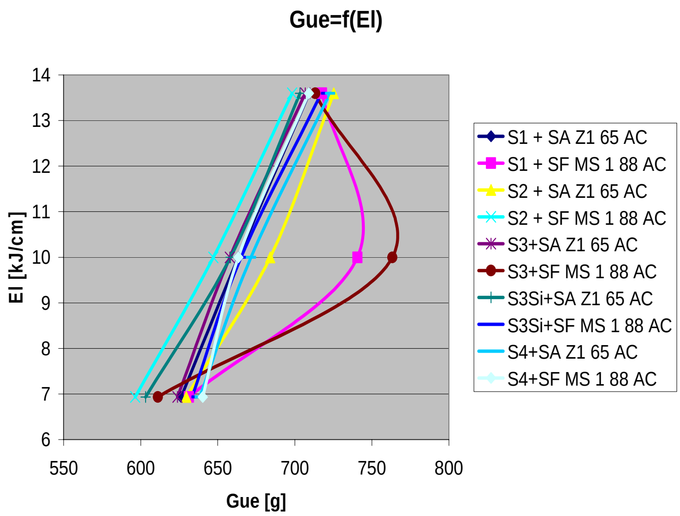

Fig. 6. Dependence G_{ue}=f(El)

The dependence between C_p and the linear energy *El* is indicated in figure 7 for each conducted experiment, for SAW.

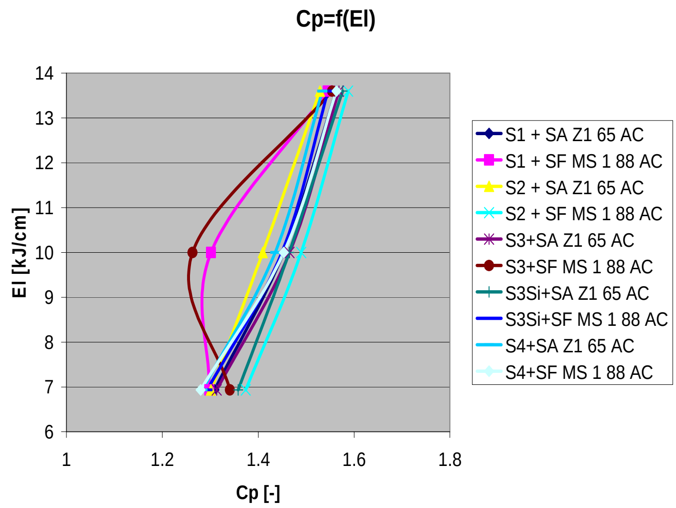

Fig. 7. Dependence C_p=f(El)

Conclusion

Analyzing the obtained experimental data we can draw the following general conclusions:

1^0. The experimental program included the following steps: choosing basic material, determine the methods for cleaning, degreasing, pickling and choice of material added, setting type and temperature of ignition of the wire, determining parameters of welding regime and comparative analysis of the results;

2^0. A different and special influence on the coefficient of pollution, have all technological parameters of welding process, achieving a minimum pollution factor when choosing the next parameters: Is = 500A, Ua = 30V, El = 10 kJ/cm;

3^0. Experimentally found that an important impact on the coefficient of pollution is a type of wire, the flux type and linear energy;

4^0. Experimentally found that for steel for carrying containers and boilers, welding regimes which are discharged into the atmosphere the lower concentrations of SO_2 and H_2S and a minimum of microparticole and metal particles.

References

1. Amza, Gh. - *Ecotehnologie,* Vol. I si II, Ed. Printech, Bucuresti, 2008;
2. *** - *Welding Health and Safety, A Field Guide for OEHS Professionals*. AIHA Press, Farifax, VA. 2002;
3. Palmer, W. G. and Eaton, J. C. - *In Effects of Welding on Health- XI*. American Welding Society, eds., Vol. XI, Miami;
4. Angelescu, F.L., Ponoran,A.L, Ciobotaru, V. - *Mediul ambiant si dezvoltarea durabila*, Editua ASE, Bucuresti, 2003;
5. *** - *Program Manual FGA 40Plus*;
6. Hewitt, P. J. - Reducing fume emissions through process parameter selections. *Occupational Hygiene* 1, pp. 35-45;

7. Hewitt, P. J. and Hirst, A. - A systems approach to the control of welding fumes at source. *Ann.occup. Hyg.* 37, pp. 297-306;
8. Pedersen, B., Thomson, E. and Stem, R. M. - Some problems in sampling analysis and evaluation of welding fumes containing Cr(VI). *Ann. occup. Hyg.* 31, pp. 325-338;
9. Zgura, Gh., Iacobescu, G., Rontescu C., Cicic, D. - *Tehnologia sudarii prin topire*, Editura Politehnica press, 2007;
10. James, M. Antonini - Health Effects of Welding*, Critical Reviews in Toxicology,* pp. 1547-6898.

Contribuții teoretice şi experimentale privind poluarea mediului prin procedeul de sudare automată sub strat de flux (SAF)

Rezumat

În lucrarea de față sunt prezentate cercetarile efectuate in vederea evidentierii tipurilor de substanțe nocive rezultate în urma sudării prin procedeul de sudare sub strat de flux (SAF), precum si valorile coeficientului de poluare total si variatia acestuia functie de parametrii regimului de sudare.