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RESEARCH ON ENVIRONMENTAL POLLUTION WHEN USING SHIELDED METAL ARC WELDING (SMAW)

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În cadrul lucrării sunt prezentate tipurile de substanţe nocive şi cantităţile determinate în urma experimentărilor utilizând procedeul de sudare manuală cu electrod învelit(SMEI) .

Se prezintă şi influenţa principalilor parametrii ai procedeului de sudare asupra coeficientului de poluare.

This paper presents the types of noxious substances and the quantities determined following the experiments using shielded metal arc welding (SMAW).

It also presents the influence of the main parameters of the welding procedure on the pollution coefficient.

Keywords: welding, environment, gas, pollution

1. Introduction

Welding is the most important non-demountable assembly method. The industrial use of welding is very expensive due to the manual labor, which amounts to about 80…90 % of the production costs [1]. In industrialized countries, 0.2 ….2 % of the labor force works in the welding field. Most of the welders work on shipyards, they build transportation means, work in civil engineering, in the petrochemical industry, in the mining industry and metallurgy [2]. These workers are exposed to smoke and toxic gas emitted following the welding processes (Table 1), which may endanger their health.

The welding operation is considered a dangerous occupation due to the following reasons [3, 4,]:

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- there are various factors that endanger the welder's health, such as temperature, burns, radiation, noise, gas, electric shock;

- great variety in the chemical composition of the metal vapors resulted during the welding processes, which vary according to the used material, the used method and the used shielded gas. The particles and gas generated during the welding operation are considered the most harmful in comparison with other reactions resulted following the welding operation.

The main dangers associated with the welding operation that affect the health of the human personnel are smoke and gas. Apart from these, a series of dangers may exist as follows: electric shock, fire and explosions, burns due to the splashes of molten metal, eye and skin diseases due to ultraviolet emissions, effects due to heat radiation, effects associated with the powerful noise during plasma arc welding [6, 7, 8].

The dangers mentioned above and the protection measures are described in Health and Safety in Welding, published by Welding Technology Institute of Australia in 2002.

Table 1.

Risk sources for welders [2]

Smoke	Gas	Radiant energy	Other risks
Aluminum	CO_2	Ultraviolet	Noise
Cadmium	CO	Visible	Burns
Chrome	NO	Infrared	Heat
Copper	NO_2		
Fluoride	O_3		
Manganese			
Magnesium			
Nickel			
Silicon			
Titanium			
Zinc			

As a general conclusion concerning the above described facts, we can say that welders are exposed to a varied mixture of toxic particles and toxic gas, which were proven to endanger a great number of workers.

Determination of the effects on health during the experimental studies is a complex task that is complicated by the existence of various influence factors and technical welding procedures [2]. However, important information can be obtained by identifying such effects with the help of animal experiments following the exposure to the inhalation of three types of welding smoke resulted after the following welding operations: - shielded metal arc welding with stainless steel electrode; - shielded metal arc welding with electrode low carbon content; - gas metal arc welding with stainless steel wire.

These three processes cover most of the used welding types and permit the examination of smoke with its numerous effects, an assertion expressed based on the fact that the greatest applicability field during welding operations used in the industry is covered by GAS metal arc welding procedures and SMAW. The smoke resulted following the GAS metal arc welding operation is relatively insoluble, whereas the smoke resulted following SMAW contains both soluble and insoluble materials. The smoke resulted following the welding of stainless steel contains chrome and nickel that are carcinogenic in this form.

The effects on health may be [3, 4]:

- ***Acute***. The effects occurred following short-term inhalation of various gas and smoke types emitted following the welding procedure may be determined by certain alteration processes of the worker's health;

- ***Chronic***. Long-term effects are not taken very much into consideration at this time, as they are mistaken for the effects arising from other factors, such as smoking.

2. Experimental stand.

In order to determine the gas and smoke amounts resulted following the welding operation we planned and built an original experimental stand model (SE-GF001).

The stand is provided with a series of elements that permit the monitoring of the welding process and also the complete taking over of the elements, (fig. 1), resulted following the welding operation, as follows: the upper side was provided with an opening for the „stick" of the measuring device; in order to allow the welder to monitor the electric arc, especially its stability, a part of the material was cut out and replaced with special glass against the light emitted by the electric arc; Room for positioning the samples to be welded.

In order to ensure the access of the filler material, electrode holder, welding torch and to initiate the welding process, the stand was provided at the lower part with an access space with the adequate dimensions. This area was sealed for the reduction of any possible gas or smoke leaks.

The stand was designed starting from the following requirements:

- material: steel:
- thickness: 5 mm:
- additional requirement: tightness;
- access to the welding place;
- maximum dimensions of the samples to be welded: 750x300x50 mm and maximum weight of the stand: 80Kg;

In Figure 2, the experimental stand is shown.

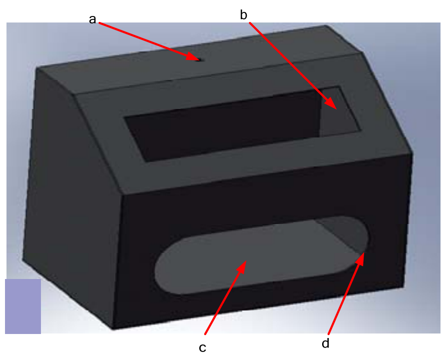

Fig. 1. Relevant elements of the SE-GF001 stand

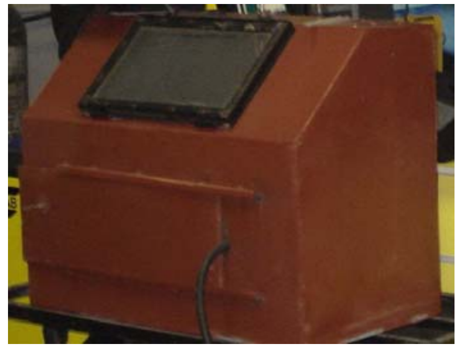
Fig. 2. Experimental stand

3. Determination mechanism of the gases [5]

In order to carry out the environmental impact measurements we used an experimental stand that also includes the GA-40 Plus analyzer.

During the measurement with the GA-40 plus device, several parameters are directly determined, such as: gas temperature, in ^{o}C, CO concentration, in ppm, NO concentration, in ppm, SO_2 concentration, in ppm , O_2 concentration, in %.

The device also has the capacity to carry out a series of calculations for the determination of other types of gases.

- CO_2 concentration, relation (1);
- NO_x concentration, relation (2). If the analyzer is provided with a sensor for the determination of the NO_2 content, the NO_x quantity will be calculated based on relation (3);
- CO concentration – not diluted, relation (4);

For the determination of CO_2 concentration the following relation is used:

$$CO_2 = CO_{2_{\max}} \left(1 - \frac{O_{2_{meas}}[\%]}{20{,}95\%} \right) \quad (1)$$

where: O_{2mas} is the oxygen quantity, expressed in %;

The following relation is used in order to determine NO_x concentration:

$$NO_x[ppm] = \frac{NO[ppm]}{0{,}95} \quad (2)$$

where: NO is the nitrogen oxide concentration, expressed in ppm;

As the GA-40Plus analyzer also has a sensor for the determination of NO_2, the NO_x concentration is determined based on the relation:

$$NO_x[ppm] = NO[ppm] + NO_2[ppm] \quad (3)$$

where: NO_2 is the nitrogen dioxide concentration, expressed in ppm;

The undiluted carbon oxide quantity CO_{nedil} is determined based on the relation:

$$CO_{nedil} = CO \cdot \lambda \quad (4)$$

where: CO - CO concentration expressed in ppm; λ - air excess

GA-40 plus can also carry out the weight calculation expressed in [mg/m^3] based on the gas concentrations expressed in [ppm], while the weight also depends on the pressure and temperature.

The GA-40 plus analyzer indicates various values expressed in [mg/m^3], called “absolute mass concentration” and “mass concentration relative to oxygen”.

During the experiments we used various relations for the determination of the masses of different gases resulted from the analyzed procedures. Thus, for the carbon oxide quantity CO, expressed in mg/m^3, the following relation was used:

$$CO[mg/m^3] = CO[ppm] \cdot A_{CO} \quad (5)$$

where: CO is the absolute mass concentration of CO (standard conditions), expressed in mg/m^3; CO is the absolute concentration (from the measurement), expressed in [ppm]; A_{CO} is a correction factor, with the values presented in Table 2.

Table 2.

Values of the correction factor standard conditions 1000hPa, 0 ^{0}C [5]

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

The NOx mass was calculated while taking into account the nitrogen dioxide concentration, determined based on the relation (3).

The calculation of CO value is carried out based on the relation below:

$$CO_{rel}[mg/m^3] = \frac{20{,}95\% - O_{2ref}}{20{,}95\% - O_{2meas}} \cdot CO[mg/m^3] \quad (6)$$

where: CO_{rel} is the CO concentration in relation to O_2, expressed in mg/m^3; O_{2ref} is the reference value of O_2, expressed in % vol; O is the measured value of O, expressed in % vol; 20,95% is O value in the pure air; CO is the measured value of CO in the burnt gases, expressed in mg/m^3;

The pollution coefficient C_p was determined based on the relation:

$$C_p = \frac{Gt_{ef}}{G_{ue}} \tag{7}$$

where: Gt_{ef} is the total weight of the filler material, expressed in g; G_{ue} – useful weight, calculated based on the relation.

$$G_{ue} = Gt_{ef} - G_p \tag{8}$$

where: Gp is the weight of the pollutants, calculated based on the relation:

$$G_p = G_{paer} + G_{ps} \tag{9}$$

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

The weight of the substances that pollute the air is calculated based on the relation:

$$G_{paer} = G_{H_2} + G_{CO} + G_{NO} + G_{NO_2} + G_{H_2S} \tag{10}$$

where: G_p is the weight of the microparticles smaller than 5μm, which remain in air or which are deposited after a long time; G_{CO} - weight of CO released into the atmosphere; G_{NO} - weight of NO released into the atmosphere; G_{NO_2} - weight of NO_2 released into the atmosphere; G_{H_2S} - weight H_2S released into the atmosphere; G_{H2} - weight of H_2 released into the atmosphere;

The weight of the substances that pollute the soil G_{ps} is calculated based on the relation:

$$G_{ps} = G_{pp} + G_{mp} \tag{11}$$

where: G_{pp} is the weight of the particles that fallon the ground; G_{mp} is the weight of the microparticles that remain in the atmosphere;

4. Experiments and results

4.1. Input data

14 electrodes types were chosen for the experiments conducted to determine the types of gases resulting by burning various types of filler materials.

In order to determine the dependences between various types of electrodes and the gas quantities and the parameters of the welding processes, the following parameters were measured during the experiments: welding current, arc voltage, bead length and welding time.

The value of the linear energy for each of the 42 experiments was calculated based on the relation [9]:

$$E_l = \eta \frac{U_a I_s}{v_s} [kJ/cm] \tag{12}$$

where: η is the efficiency of the welding procedure; U_a is the arc voltage, expressed in V; I_s is the intensity of the welding current, expressed in A; v_s is the welding speed, expressed in cm/s.

4.2. Obtained results

Before starting the deposits by welding all steel plates were weighed, and the obtained results are indicated in Table 2 and 3.

Table 2

Values of the masses of base plates used during the experiments – for shielded metal arc welding

Nr. Crt.	Electrod type	M plate [g]
1	AWS 5.1 E7018	496
2		618
3		376
4	AWS 5.1 E7018	380
5		392
6		330
7	AWS 5.5 E 8018G	520
8		442
9		444
10	AWS 5.5 E7018 G	442
11		428
12		738
13	AWS 5.5 E 8018	523
14		658
15		676
16	AWS 5.5 E8018 B2	600
17		594
18		560
19	AWS 5.1 E7018	566
20		442
21		430

Table 3

Values of the masses of base plates used during the experiments – for shielded metal arc welding

Nr. Crt.	Electrod type	M plate [g]
1	AWS 5.1 E 7048	322
2		484
3		340
4	AWS 5.4 E309-16	466
5		438
6		442
7	DIN 8573 E-Fe-B2	334
8		402
9		432
10	AWS 5.4 E307-15	280
11		446
12		434
13	AWS 5.5 E8018-B2	632
14		672
15		622
16	AWS 5.5 E8018-B2	534
17		668
18		676
19	E10-UM-65-GR	632
20		626
21		528

The obtained values are indicated in Table 4, where the following encoding was used: - DEXT is the diameter exceeding the electrode shell; DVM is the diameter of the metal rod; CNVM is the quantity of unmelted metal rod; CNINV is the unmelted shell quantity; GINV is the shell weight; GVM is the weight of the metal rod; CDVM is the deposit quantity of metal rod; CDINV is the deposited shell quantity; B – Thick and B - Medium – type of shell defined as the relation between DEXT and DVM

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

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.

Table 4.

Value of the welding parameters

Nr crt	Denum.	DEXT [mm]	DVM [mm]	DEXT/DVM [-]	GVM [g]	GINV [g]	Parametrii					
							Is [A]	Ua [V]	lc [cm]	t [s]	Vs [cm/s]	El [kJ/cm]
1	AWS 5.1 E7018	3.6	2	1.8	8	4	60	17	11	25	0.44	1.855
2					8	4	70	18	13	21	0.619	1.628
3					8	4	80	19	11.5	19	0.6053	2.009
4	AWS 5.1 E7018	4.2	2.5	1.68	12	10	80	17	16	52	0.3077	3.536
5					12	10	90	18	15	54	0.2778	4.666
6					12	10	100	19	14	49	0.2857	5.32
7	AWS 5.5 E 8018G	5.4	3.2	1.6875	28	16	100	17	23.0	88	0.2614	5.203
8					28	16	120	19	15.0	71	0.2113	8.634
9					28	16	145	20	15.0	67	0.2239	10.36
10	AWS 5.5 E7018 G	4.7	2.5	1.88	18	6	75	17	18.0	65	0.2769	3.683
11					18	6	93.0	19	15.0	57	0.2632	5.372
12					18	6	110	20	15.0	50	0.3	5.867
13	AWS 5.5 E 8018	4.6	2.5	1.84	12	8	70	17	17.5	54	0.3241	2.938
14					12	8	85	19	14.0	49	0.2857	4.522
15					12	8	100	20	10.5	41	0.2561	6.248
16	E8018 B2	4.5	2.5	1.8	12	10	85	17	11.0	31	0.3548	3.258
17					12	10	88	17	14.0	45	0.3111	3.847
18					12	10	90	18	10.0	33	0.303	4.277
19	AWS 5.1 E7018	7	4	1.75	44	26	140	19	30.0	65	0.4615	4.611
20					44	26	170	20	27.0	74	0.3649	7.455
21					44	26	200	21	30.2	55	0.5491	6.119
22	AWS 5.1 E 7048	4.9	3.25	1.50769	22	10	140	19	15.1	45	0.3356	6.342
23					22	10	145	20	17.0	45	0.3778	6.141
24					22	10	150	21	16.0	44	0.3636	6.93
25	AWS 5.4 E309-16	5.1	3.25	1.56923	22	10	80	17	14.5	60	0.2417	4.502
26					22	10	90	18	17.3	53	0.3264	3.97
27					22	10	100	19	13.0	50	0.26	5.846
28	DIN 8573 E-Fe-B2	4.6	2	2.3	14	10	65	17	13.5	55	0.2455	3.601
29					14	10	88.0	18	13.0	43	0.3023	4.192
30					14	10	110	20	14.5	46	0.3152	5.583
31	AWS 5.4 E307-15	5.3	3.25	1.63077	24	10	70	17	14.5	35	0.4143	2.298
32					24	10	85	18	17.0	42	0.4048	3.024
33					24	10	100	20	18.0	40	0.45	3.556
34	AWS 5.5 E8018-B2	5.8	3.25	1.78462	37	18	110	23	3.1	10	0.31	6.67
35					37	18	120	23	2.7	10	0.27	8.36
36					37	18	135	23	3.3	10	0.33	7.69
37	AWS 5.5 E8018-B2	6.5	4.00	1.625	40	22	140	23	9.4	10	0.94	2.80
38					40	22	165	23	2.5	10	0.25	12.41
39					40	22	190	23	3.8	10	0.38	9.40
40	E10-UM-65-GR	9	4.00	2.25	34	64	160	23	1.7	10	0.17	17.69
41					34	64	175	23	2.1	10	0.21	15.67
42					34	64	190	23	2	10	0.2	17.86

The values of gases obtained, is shown in Table 5.

Table 5.

Value of the gases and pollution coefficient

Nr crt	Denum.	Gt_{ef} [g]	CO [ppm]	NO [ppm]	NO_2[ppm]	NO_x[ppm]	SO_2 [ppm]	H_2S [ppm]	H_2 [ppm]	Gpaer [g]	Gpp [g]	Gmp [g]	Gps [g]	Gp [g]	Gue [g]	Cp
1		12	40	35	0	35	1	0	11	1.28537161	5	1	6	7.2854	4.71462839	2.5453
2		12	43	73	0	73	2	1	25	2.28627574	3.74	2.26	6	8.2863	3.71372426	3.2313
3	AWS 5.1 E7018	12	73	28	0	28	0	0	14	1.5066241	3.88	0.12	4	5.5066	6.4933759	1.848
4		22	84	29	1	29	0	1	14	1.6646616	6.54	1.46	8	9.6647	12.3353384	1.7835
5		22	69	39	0	39	0	0	29	1.85430659	7.8	2.2	10	11.854	10.1456934	2.1684
6	AWS 5.1 E7018	22	42	90	0	90	0	0	37	2.72878072	8.6	0.4	9	11.729	10.2712193	2.1419
7		44	61	28	0	28	1	0	14	1.39072994	13.5	4.5	18	19.391	24.6092701	1.7879
8		44	51	18	0	18	2	0	6	1.00090412	19.3	0.7	20	21.001	22.9990959	1.9131
9	AWS 5.5 E 8018G	44	82	73	0	73	0	0	37	2.79199571	18	6	24	26.792	17.2080043	2.5569
10		24	79	26	0	26	0	0	13	1.51715994	8.5	1.5	10	11.517	12.4828401	1.9226
11		24	96	20	0	20	0	0	13	1.5698391	7	0	7	8.5698	15.4301609	1.5554
12	AWS 5.5 E7018 G	24	103	30	0	30	0	0	23	1.95966492	10.4	2.6	13	14.96	9.04033508	2.6548
13		20	66	23	0	23	0	0	14	1.32751494	8.7	4.3	13	14.328	5.67248506	3.5258
14		20	78	26	0	26	1	0	11	1.49608827	10.3	0.7	11	12.496	7.50391173	2.6653
15	AWS 5.5 E 8018	20	89	32	0	32	0	0	17	1.79109159	10.2	1.8	12	13.791	6.20890841	3.2212
16		22	103	37	0	37	0	0	16	2.03341575	11.2	0.8	12	14.033	7.96658425	2.7615
17		22	116	42	0	42	1	0	16	2.28627574	7.5	2.5	10	12.286	9.71372426	2.2648
18	E8018 B2	22	123	49	0	49	0	0	19	2.52859989	8.2	3.8	12	14.529	7.47140011	2.9446
19		70	43	37	0	37	0	0	23	1.4750166	37.6	2.4	40	41.475	28.5249834	2.454
20		70	58	42	0	42	0	0	29	1.80162742	27.8	6.2	34	35.802	34.1983726	2.0469
21	AWS 5.1 E7018	70	58	48	0	48	0	0	31	1.94912908	37.8	4.2	42	43.949	26.0508709	2.6871
22		32	88	27	0	27	0	1	25	1.77001992	13.5	0.5	14	15.77	16.2299801	1.9717
23		32	103	31	0	31	0	0	28	2.03341575	12.3	1.7	14	16.033	15.9665843	2.0042
24	AWS 5.1 E 7048	32	108	37	0	37	0	0	34	2.2757399	11.8	2.2	14	16.276	15.7242601	2.0351
25		32	55	22	0	22	0	0	18	1.23269245	15.4	0.6	16	17.233	14.7673076	2.1669
26		32	64	28	0	28	0	0	21	1.48555244	13.8	0.2	14	15.486	16.5144476	1.9377
27	AWS 5.4 E309-16	32	78	35	0	35	0	0	29	1.86484242	18.2	1.8	20	21.865	10.1351576	3.1573
28		24	53	61	0	61	0	0	46	2.32841907	15.2	0.8	16	18.328	5.67158093	4.2316
29		24	60	65	0	65	0	0	57	2.60235072	12.2	1.8	14	16.602	7.39764928	3.2443
30	DIN 8573 E-Fe-B2	24	89	76	0	76	0	0	58	3.15021403	9.9	0.1	10	13.15	10.849786	2.212
31		34	131	28	0	28	0	0	23	2.21252491	19.3	2.7	22	24.213	9.78747509	3.4738
32		34	149	39	0	39	0	1	28	2.69717322	19.5	2.5	22	24.697	9.30282678	3.6548
33	AWS 5.4 E307-15	34	151	46	0	46	0	0	33	2.90788988	19.3	0.7	20	22.908	11.0921101	3.0652
34		28	80	9	1	9	1	4	1	1.10626245	10	0.8937	10.894	12	16	1.75
35		30	90	10	1	10	1	5	3	1.26429995	11	0.7357	11.736	13	17	1.7647
36	AWS 5.5 E8018-B2	34	103	20	0	20	9	3	9	1.72787659	14	4.2721	18.272	20	14	2.4286
37		28	52	32	0	32	2	2	5	1.31697911	10	2.7357	12.736	14.053	13.9473208	2.0076
38		38	44	18	0	18	1	1	7	0.93768913	11	3.115	14.115	15.053	22.9473208	1.656
39	AWS 5.5 E8018-B2	42	57	7	1	7	1	1	11	0.8955458	12	3.0518	15.052	15.947	26.0526792	1.6121
40		40	110	38	2	38	3	6	6	2.13877408	10	5.8612	15.861	18	22	1.8182
41		38	146	20	1	20	1	6	7	2.11770241	8	3.8823	11.882	14	24	1.5833
42	E10-UM-65-GR	42	156	26	1	26	4	8	18	2.51806406	8	3.4819	11.482	14	28	1.5

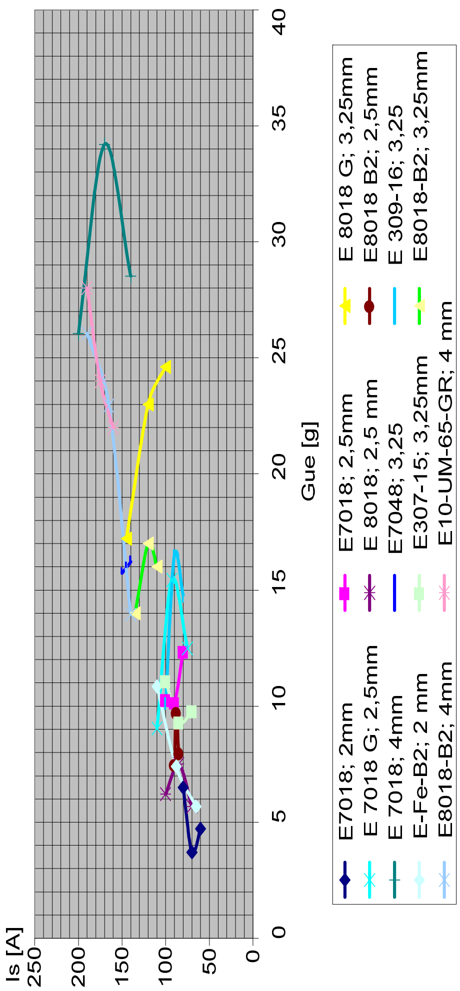

Fig. 3. Dependence G_{ue}=f(Is) – SMAW

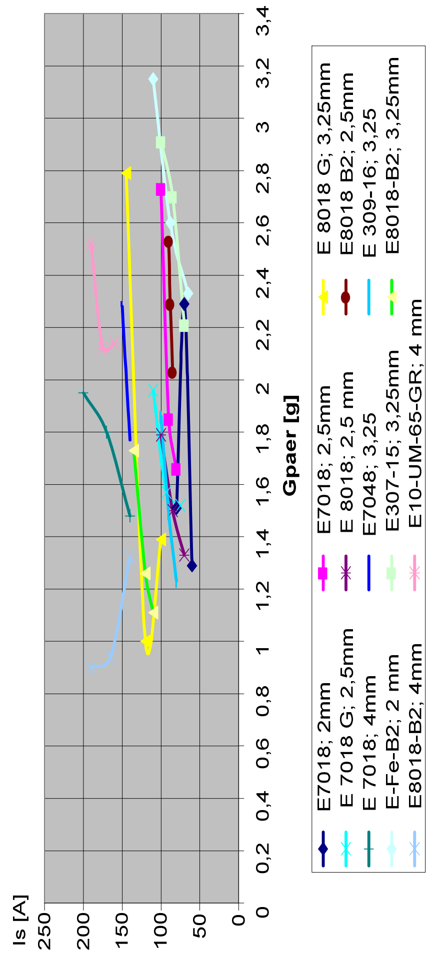

Fig. 4. Dependence G_{paer}=f(Is) SMAW

The dependence between Cp (pollution coefficient) and the intensity of the welding current is indicated in Figure 5 for each conducted experiment, for SMAW.

Analyzing Figure 6 we can observe that the maximum values of the $CO_{average}$ quantity were obtained for E307-15 electrode and amounted to 143.7 ppm, and the minimum values, 51 ppm, which values are approx. three times lower than the maximum values, for E8018-B2. We mention that E307-15 electrode is an electrode used for welding of high alloyed steels and E8018-B2 electrode is a basic electrode used on a large scale for obtaining welds with high strength.

Noteworthy is that when using E10-UM-65-GR electrode that is ment for hard facing, the CO average value was lower by 6.3 ppm than when E307-15 electrode was used.

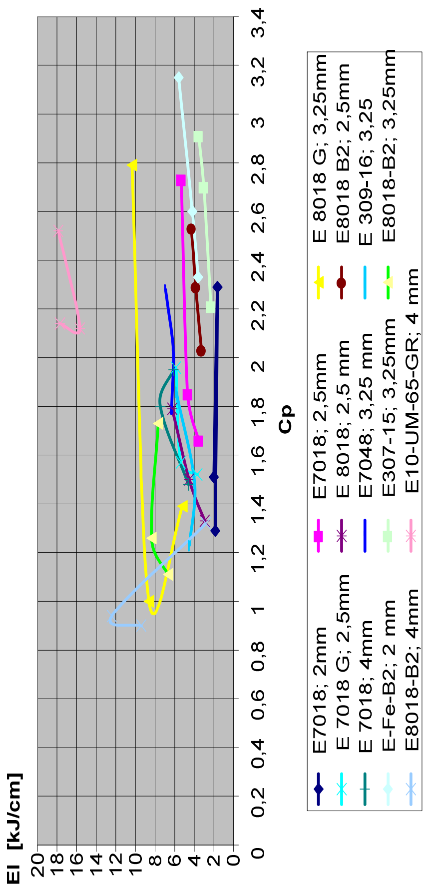

Fig. 5 Dependence C_p=f(El) SMAW

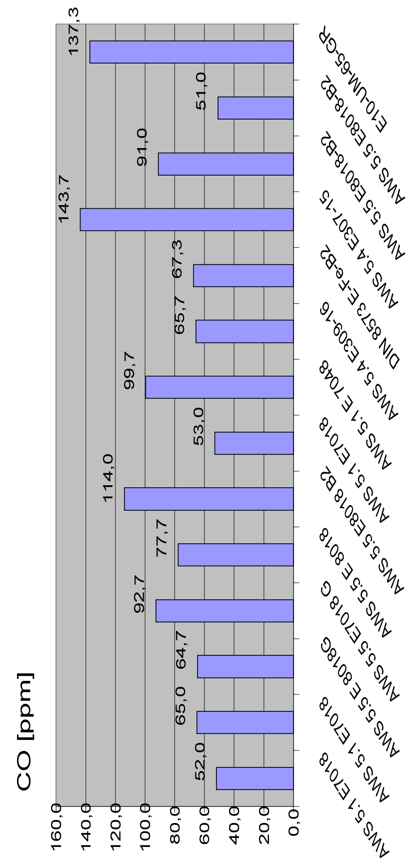

Fig. 6. Comparison between the average CO values, for SMAW

Analyzing Figure 7 it can be observed that the maximum values of the $NO_{average}$ quantity were obtained for E-Fe-B2 electrode, 67.3 ppm, and the minimum values, 13 ppm (approx. five times lower than the maximum values) for E8018-B2.

Moreover, it can be observed that the following high value is obtained during the deposit with E7018 electrodes, and it amounts to 52.7 ppm, an electrode that is widely used in the industry.

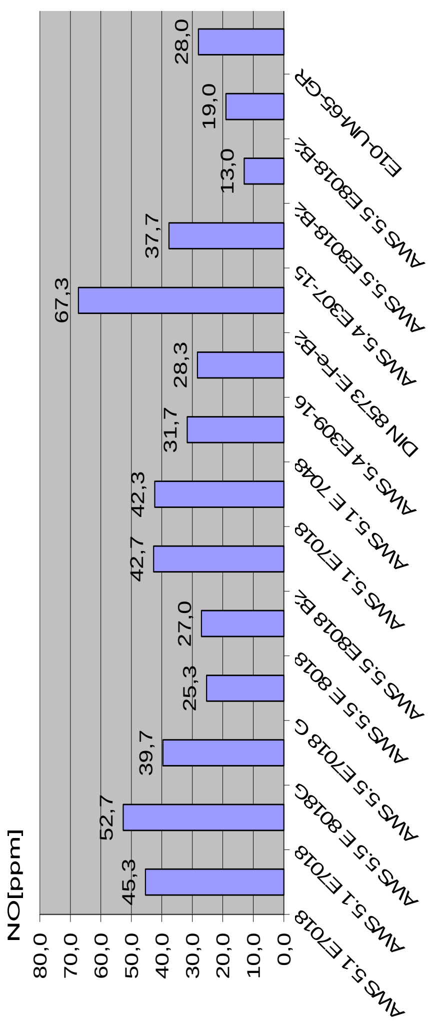

Fig. 7. Comparison between average NO values for SMAW

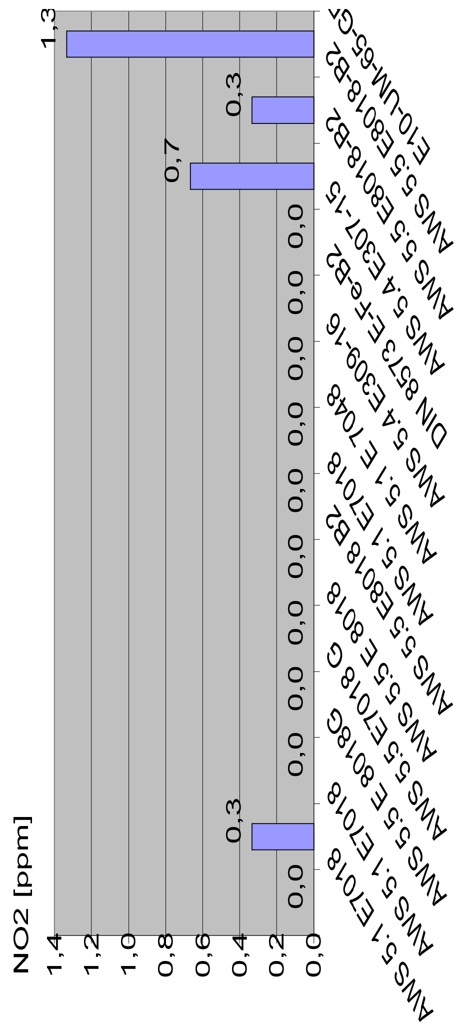

Fig. 8. Comparison between average NO_2 values for SMAW

As far as the NO_2 emission is concerned, Figure 8, we observed that indications regarding the existence of this gas resulted only in four cases out of the analyzed fourteen: E7018; E8018-B2 with the diameter of 3.25 mm, E8018-B2 with the diameter of 4mm and E10-UM-65-GR with the diameter of 4mm.

The highest value of NO_2, 1.3 ppm, was obtained when E10-UM-65-GR electrode with the diameter of 4mm was used.

As far as the average SO_2 emission is concerned, Figure 9, it was observed that only for seven electrodes out of the analyzed fourteen information regarding the existence of this gas resulted: E7018; E8018-G, E8018, E8018-B2 and E10-UM-65-GR.

The highest value of SO_2, 1.3 ppm, was obtained when E8018-B2 electrode with the diameter of 3.25 mm was used.

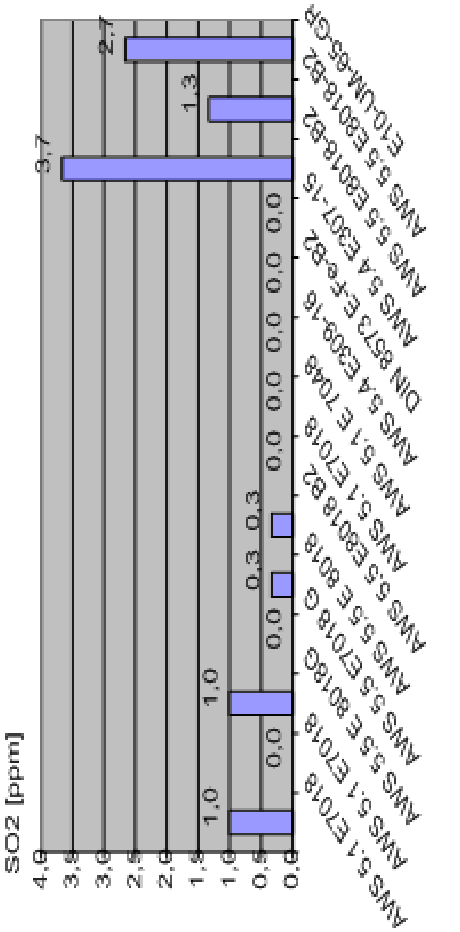

Fig. 9. Comparison between average SO_2 values for SMAW

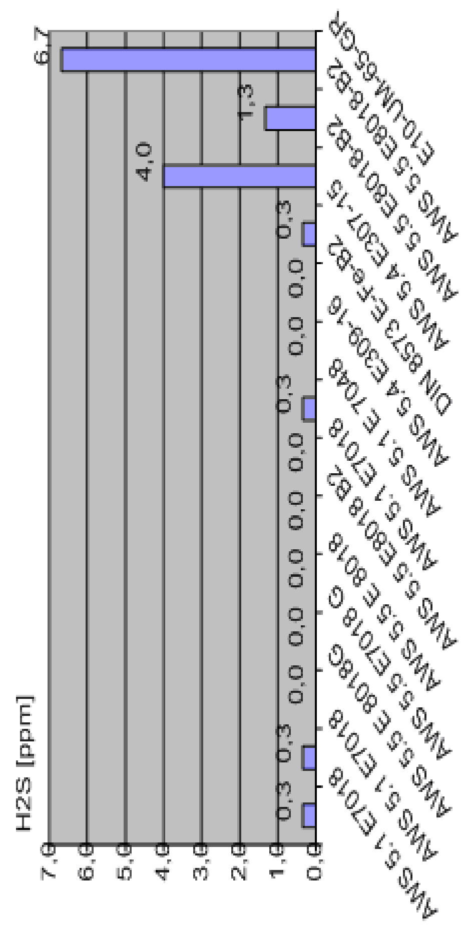

Fig. 10. Comparison between average H_2S values for SMAW

Analyzing the average variation of the H_2S quantities, Figure 10, it was observed that indications regarding the existence of this gas only for seven electrodes resulted:

- maximum average values for E10-UM-65-GR electrodes, 6.7 ppm;
- minimum values for E7018; E7048; E307-15 electrodes, 0.3 ppm.

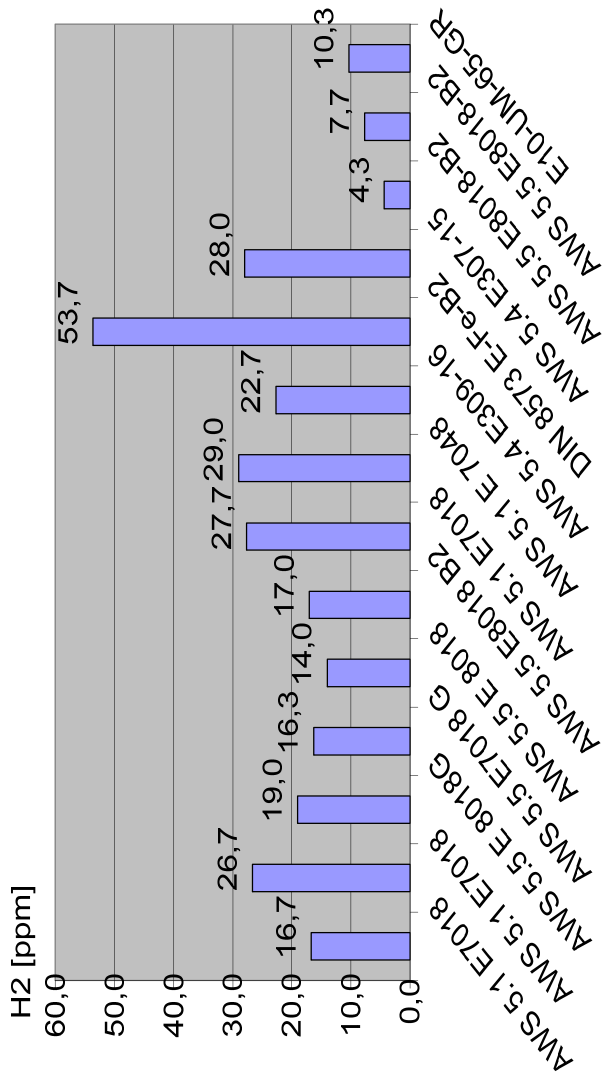

Fig. 11. Comparison between average H_2 values for SMAW

Analyzing Fig. 11, it can be observed that for all deposits, irrespective of the nature of the shell, the diameter or length of the electrode, the analyzer indicated the presence of H_2 as follows that maximum average values for E-Fe-B2 electrode, of 53.7 ppm and the minimum average values for E8018-B2 electrode, of 4.3 ppm.

5. Conclusions

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

- From the shielded metal arc welding process, SMAW, gases that affect the air and the welders results: CO, NO, NO_2, H_2, SO_2, H_2S;
- From the shielded metal arc welding process, a series of micro and macroparticole that pollute the enviroment results;
- The amount of gas depends on the type of the coating, on the diameter and quantity of material deposited by metal rods and on the coating;
- One of the most noxions gases for welders, H_2S was detected in seven of the fourteen cases examined;
- There is no linear dependence between the resulted amount of gases and the linear energy;
- Research should be carried out to establish the dependence between the chemical composition of the coating and the gas quantities resulting from the welding preocess.

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