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Theoretical and Experimental Contributions Concerning the Environmental Impact of Processes of Oxy-gas Welding Flame (SF)

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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 flame (SF) and the coefficient values of total pollution and its variation with the parameters of the welding regime.

Key words: *environmental, impact, oxy-gas welding*

Introduction

Welding gas flame makes part of the welding processes that use thermo-chemical energy. Heat source used to heat local parts melting temperatures form a gas flame.
The gas flame can fuse unalloyed and alloyed steel, gray iron, nonferrous metals and their alloys (Al, Cu, Zn, Ni, Mg, I, Bz, etc.) and precious metals.
Oxyacetylene welding flame is formed by igniting a gaseous mixture consisting of fuel gas - acetylene - and oxygen at the outlet of a burner.

Theoretical Research

Welders can adjust the oxy-acetylene flame to be burnt, neutral or oxidizing flame adjustment is made by adding oxygen. Type of flame area is often used for welding and cutting. Welders use neutral flame as starting point to facilitate obtaining other types of fire. This flame is produced when, by slightly opening the valve for oxygen, are visible only two areas of the flame, at this point is completely burnt in oxygen acetylene welding and in ambient air. The flame is chemically neutral. The two sides of the flame are: the core flame light blue and dark blue flame outside. Flame core is where oxygen and acetylene are combined; this place is the hottest of the flame having around 3300 °C [1].

Excess acetylene flame causes carbonization. This type of flame is characterized by three zones: core flame, white hot zone "to acetylene and the outside. This type of flame is observed when oxygen is introduced for the first time in acetylene burning. "Up" in welding is the size of 2X or

3X, X understood the core flame length. Carbon burning us and it insulates the flame combustion temperature decreases to 2760 ° C [2].

Oxide is the third type flame-retardant obtainable. This type of flame is obtained when welders plus a larger amount of oxygen in neutral flame. This type of flame develops a higher combustion temperature than the other two types of flames. Oxidizing flame is called because of the effect it has on the material. Oxidizing flame creates unwanted oxides on most metals.

Complete combustion of acetylene takes place after the reaction:

$$C_2H_2 + 2.5\ O_2 \rightarrow 2\ C\ O_2 + H_2\ O \tag{1}$$

In reality, the combustion process is more complex for during combustion, acetylene undergoes a series of changes in either the following relations [2].

$$C_2H_2 \rightleftarrows 2\ C + 2H_2 \tag{2}$$

At approx. 1073 K, acetylene disociează after reaction:

$$2C_2H_2 \rightleftarrows CH_4 + 3C \tag{3}$$

Following that is more stable than methane hydrocarbon acetylene. At temperatures above 12730K, methane breaks down into components, as follows:

$$CH_4 \rightarrow C + 2\ H_2 \tag{4}$$

If the welding process is conducted in the presence of oxygen, decomposition products reacting with oxygen and burn properly. In the presence of oxygen, decomposition takes place approximately as follows:

Acetylene is a hydrocarbon saturated us, it will separate easily and reacts strongly with oxygen. Once the first product formed by oxidation, or even the slightest amount, it accelerates the process decurie as follows:

$$C_2H_2 + O = C_2H_2O \tag{5}$$

$$C_2H_2O + O_2 = C_2H_2O_2 + O \tag{6}$$

$$C_2H_2O_2 \rightarrow HCHO + CO \tag{7}$$

$$H_2 + CO$$

This chain of oxidation reactions to form products becoming more stable. Theoretically, the decomposition products are H2 and CO, is water gas. In reality, however, can not avoid dissociation of acetylene in the reaction components as above, is:

$$C_2H_2 \rightarrow 2C + H_2 \tag{8}$$

after a certain amount of carbon that occur in elementary. Some carbon is oxidised to carbon monoxide and the rest remains free in flame.

Necesary oxygen in carbon monoxide oxidation of carbon, oxygen is called primary, which is consumed in the cylinder. Reaction takes place is of the form:

$$2\ C + H_2 + O_2 \rightarrow 2\ CO + H_2 + 450\ 000\ kJ/kmol \tag{9}$$

Dissociation process is merely a preparation for complete combustion of fuel. Combustion itself takes place after the reaction:

$$CO + O \rightleftarrows CO_2 \tag{10}$$

$$H_2 + O \rightleftarrows H_2O \tag{11}$$

To effect simultaneous reactions can be written above the real reaction of the form:

$$2\ CO + H_2 + O_2 \rightarrow 2\ CO_2 + H_2O + 850\ 000\ kJ/kmol \tag{12}$$

Welders can adjust the oxy-acetylene flame to be burnt, neutral or oxidizing, classification being made by the ratio of O_2 and C_2H_2, the relationship (13).

$$k = \frac{O_2}{C_2H_2} \tag{13}$$

If k = 1.1 ... 1.2. , the flame is neutral; $k \geq$ 1.1 ... 1.2. , the flame is oxidizing; $k \leq$ 1.1 ... 1.2, the flame is reducing.

Besides the above reactions, can be a series of reactions like [4,5,6,7]:
- Forming of CO, by these reactions:

$$6Fe_2O_3 + 2C = 4Fe_3O_4 + 2CO\uparrow \tag{14}$$

$$2Fe_3O_4 + 2C = 6FeO + 2CO\uparrow \tag{15}$$

$$2FeO + 2C = 2Fe + 2CO\uparrow \tag{16}$$

- Formation of CO_2, both the arc and molten metal bath formed from melting material addition and material basis, as follows:

$$C + O_2 = CO_2\uparrow \tag{17}$$

$$2H_2O + C = H_2\uparrow + CO_2\uparrow \tag{18}$$

$$6Fe_2O_3 + 2CO = 4Fe_3O_4 + CO_2\uparrow \tag{19}$$

$$2Fe_3O_4 + 2CO = 6FeO + CO_2\uparrow \tag{20}$$

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

$$N_2 + O = N + NO\uparrow \tag{21}$$

$$NCO + O = CO\uparrow + NO\uparrow \tag{22}$$

$$O_2 + N = O\uparrow + NO\uparrow \tag{23}$$

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

$$S + O_2 = O\uparrow + SO\uparrow \tag{24}$$

$$SO + O_2 = O\uparrow + SO_2\uparrow \tag{25}$$

$$SO_2 + O_2 = O\uparrow + SO_3\uparrow \tag{26}$$

-Mycropowders formation or metal powders, as follows:

$$\frac{2}{3}Fe_2O_3 + 2CO = \frac{4}{3}Fe + 2CO_2\uparrow \tag{27}$$

$$\frac{1}{2}Fe_3O_4 + 2CO = \frac{3}{2}Fe + 2CO_2\uparrow \tag{28}$$

$$2FeO + 2CO = 2Fe + 2CO_2\uparrow \tag{29}$$

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.

The amount of gas obtained by direct measurement (O_2, CO, NO, SO_2) [8]

In the measurements to directly determine the following parameters:

o gas temperature, expressed as a °C;
o CO concentration in ppm;
o NO concentration in ppm;
o SO $_2$ concentration in ppm;
o CO_2 concentration in%.

Calculating the concentration of CO_2 [8]

$$CO_2 = CO_{2_{\max}} \left(1 - \frac{O_{2_{meas}}[\%]}{20{,}95\%}\right) \tag{30}$$

Calculating the concentration of NO_x [8]

$$NO_x[ppm] = \frac{NO[ppm]}{0{,}95} \tag{31}$$

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

$$NO_x[ppm] = NO[ppm] + NO_2[ppm] \tag{32}$$

Determination of CO undiluted [8]

$$CO_{undil} = CO \cdot \lambda \tag{33}$$

where CO is the concentration of CO, - excess air

Determination of gas mass components [8]

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, is the relationship of the form:

$$CO[mg/m^3] = CO[ppm] \cdot A_{CO} \tag{34}$$

where: CO [mg / m 3] is the absolute mass of CO (standard conditions), CO [ppm] - absolute concentration (of measurement) CO - correction factor whose values are given in Table 2

Table 2. The values of correction factor at standard conditions 1000hPa,

Gaz	$A\left[\frac{mg}{m^3 \cdot ppm}\right]$
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 NO2 factor.

- Determine the mass of CO based on the relative concentrations of A in gas concentration. Relationship is made using a form:

$$CO_{rel}\left[mg/m^3\right] = \frac{20{,}95\% - O_{2ref}}{20{,}95\% - O_{2meas}} \cdot CO\left[mg/m^3\right] \quad (35)$$

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

Defining and setting the coefficient of pollution [3]

Pollution coefficient C_p can establish a relationship based on calculation of the form:

$$C_p = \frac{M_t}{m_d} \quad (36)$$

where: M_t is the total mass of material added, in g, m_d - board filed:

$$M_t = m_s + m_{C_2H_2} + m_{O_2} + m_{pa} + m_{pned} \quad (37)$$

where: $m_s = m_d$, m_{pned} - undetectable gas mass, m_{pa}, is the mass of pollutants

$$m_{p_{ned}} = (m_{C_2H_2} + m_{O_2}) - m_{pa} \quad (38)$$

where is m_{paer} is mass substances that pollute the air, m_{ps} - mass substances that pollute the soil.

Mass substances that pollute the air is calculated with relation:

$$m_{pa} = m_{H_2} + m_{CO} + m_{NO} + m_{NO_2} + m_{H_2S} + m_{SO_2} \quad (39)$$

In that: m_{CO} – CO mass emitted into the atmosphere; m_{NO} - NO mass emitted into the atmosphere; - m_{NO2} mass emitted into the atmosphere; m_{H2S} - weight emitted into the atmosphere; m_{H2} - mass emitted into the atmosphere.

Experimental Results

Basic material, added material, technological parameters

Basic material chosen was steel S235JR, whose chemical composition is shown in Table 3.

Table 3. S235JR steel chemical composition (the sample of liquid steel)

Name material	Symbols standardized	No. standard	Chemical composition					
			C [%]	**Mn [%]**	**Şi [%]**	**S [%]**	**P [%]**	Other elements **[%]**
Steel for boilers and pressure vessels	**S235JR**	**NF EN 10028-2**	Max. 0.17	1,40	max. 0,30	max. 0,045	max. 0,045	N=0.09

Added material used in the experiments was E70S wire whose chemical composition is shown in Table 4.

Table 4. Chemical composition of wire E70S

Symbols standardized	No. standard	Chemical composition		
		C [%]	**Mn [%]**	**Si [%]**
E70S	**AWS A5.18-93**	Max.0.17	1,40	max. 0,30

Before starting experiments was necessary to collect information of the kind shown in Table 5.

Table 5. Initial Information

No. crt.	Material added	Diameter [mm]	G_{totala} the wire [g]	Table plate [g]	Debit C_2H_2 [m3/h]	O_2 [m3/h]	Type Flame
1	Steel E70S	2.4	10	614	0.15	0.15	normal fuel oxidizing
2	Steel E70S	2.4	10	616	0.15	0.175	normal fuel oxidizing
3	Steel E70S	2.4	10	622	0.2	0.175	normal fuel oxidizing

System parameters for submission are shown in Table 6.

Table 6. Parameters of filing system

No.crt.	Material added	ts [s]	Lc [mm]	vs [mm/s]	The total weight after recovery [g]	Steel by [g]
1	Steel E70S	73	40	0.55	616	2
2	Steel E70S	61	45	0.74	622	6
3	Steel E70S	73	65	0.89	626	4

It is an indication that times were different preheating as specified in Table 7.

Table 7. Preheating times

No.crt.	Material added	Type Flame	For preheating [s]
1	Steel E70S	normal	23s
2	Steel E70S	fuel	36s
3	Steel E70S	oxidizing	22s

Figure 1 is indicated oven designed and conducted to determine the types and quantities of gases arising from welding through various methods.

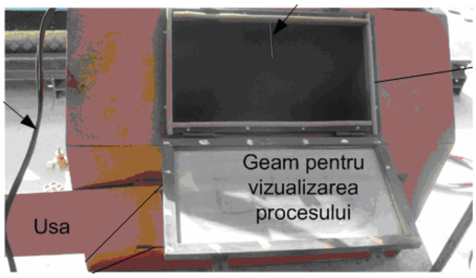

Fig. 1. Oven

Experimental Results

In Figure 2 are shown the types of flame used in the 3 experiments and shown in Figure 3 is obtained after submitting a bow.

a) normal - Experiment 1 b) fuel-Experiment 2 c) oxy-3 Experiment

Fig. 2. Types of flame used

Fig. 3. The cord conducts obtained in 1

In Table 8 are the quantities of gases such as C_2H_2 and O_2 consumed during each experiment

Table 8. Weights gas consumed

No crt.	Flow rate C_2H_2 [m3/h]	Flow rate O_2 [m3/h]	t [h]	Density C_2H_2 [g/m3]	Density O_2 [g/m3]	Expenditure C_2H_2 [g]	Expenditure O_2 [g]	TOTAL [g]	Mpned
1	1.5	1.5	0.02028	1095	1429	33.30625	43.46542	76.77167	75.36
2	1.5	1.75	0.01694	1095	1429	27.83125	42.37382	70.20507	28.01
3	2	1.75	0.02028	1095	1429	44.40833	50.70965	95.11799	90.08

It is an indication that the experiments were recorded with a video camera and the film product was manufactured in the sense that AAU was extracted frames for each second of experiments. 3 Such frames are shown in Figure 4.


a) 105 sec values EXP1


b) 122 sec values EXP2


c) 073 sec values EXP3

Fig. 4. Frames

The values obtained, corresponding to each experiment, for each type of gas recorded by the measuring device are shown in Tables 9, 10 and 11.

Table 9 (abstract). Gas values - Experiment 1

No. second	Value gas [ppm]					
	CO	NO	NO_2	SO_2	H_2S	NOX
1	0	20	3	4	1	23
11	0	26	3	4	1	29
12	0	26	3	4	1	29
13	0	26	3	4	1	29
21	0	11	3	5	0	14
22	0	11	3	5	0	14
35	0	10	3	6	0	13
36	0	10	3	6	0	13
37	2	10	3	7	0	13
38	10	9	3	7	0	12
43	40	3	3	9	0	6
44	40	3	3	9	0	6
45	40	3	3	9	0	6
46	51	0	3	9	0	3
52	79	0	3	10	0	3
86	155	0	3	14	0	3
87	155	0	3	14	0	3
88	155	0	3	13	0	3
122	118	0	1	6	0	1

Table 10 (abstract). Gas values - Experiment 2

No. Crt.	Value gas [ppm]					
	CO	NO	NO2	SO2	H2S	NOX
1	0	0	1	5	0	1
43	54	0	4	11	0	4
44	54	0	4	11	0	4
93	133	0	4	31	0	4
94	133	0	4	31	0	4
113	215	0	0	2314	0	0
114	215	0	0	2314	0	0
115	229	0	0	2792	0	0
116	229	0	0	2792	0	0
123	369	0	0	3711	0	0
124	369	0	0	3711	0	0
125	429	0	0	3642	0	0
138	484	0	0	2424	0	0

Table 11 (abstract). Gas values - Experiment 3

No. Crt.	Value gas [ppm]					
	CO	NO	NO2	SO2	H2S	NOX
69	199	75	2	122	0	77
70	199	75	2	122	0	77
71	205	74	2	122	0	76
72	206	74	2	122	0	76
73	211	72	2	121	0	74
74	211	72	2	121	0	74
75	216	72	2	120	0	74
76	216	72	2	120	0	74
77	222	71	2	120	0	73
78	222	71	2	120	0	73
79	230	70	2	119	0	72
80	230	70	2	119	0	72
97	275	64	3	113	0	67
98	275	64	3	113	0	67
157	134	0	0	99	0	0
158	134	0	0	99	0	0

The maximum amounts of gas detected is shown in Table 12.

Table 12. Maximum values of gas found during experiments

Maximum values	Gas Maximum Value [ppm]											
	CO	Timp [s]	NO	Timp [s]	NO_2	Timp [s]	SO_2	Timp [s]	H_2S	Timp [s]	NOX	Timp [s]
Experiment 1	160	90	26	9	4	40	14	81	1	1	29	13
Experiment 2	512	133	10	103	4	29	3711	123	0	-	10	103
Experiment 3	311	123	103	49	3	49	135	1	0	-	106	49

The results of the coefficient of pollution for appropriate values of a second experiment are shown in the table below.

Table 13. Coefficient values of pollution

No crt	Denu.	DVM [mm]	CDVM [g]	M+CS [g]	M_{placa} [g]	m_d [g]	Gt_{ef} [g]	CO [ppm]	NO [ppm]	NO_2[ppm]	NO_x[ppm]	SO_2 [ppm]	H_2S [ppm]	H_2 [ppm]	Gpaer [g]	Cp
1	Steel E70S	2.4	2	616	614	2	79	111	0	4	4	15	0	0	1.41	77.772
2			6	622	616	6	76	347	0	0	0	3658	0	0	42.20	24.402
3			4	626	622	4	99	182	83	3	86	124	0	0	5.04	48.559

Based on figures shown in previous tables were drawn gas variations indicated in the following figures.

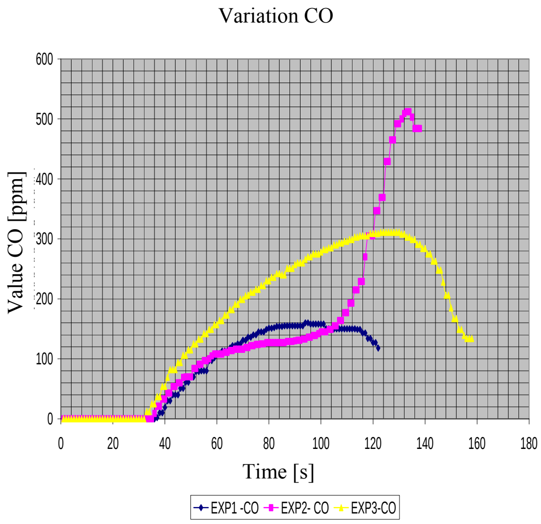

Fig. 5. Variation of CO

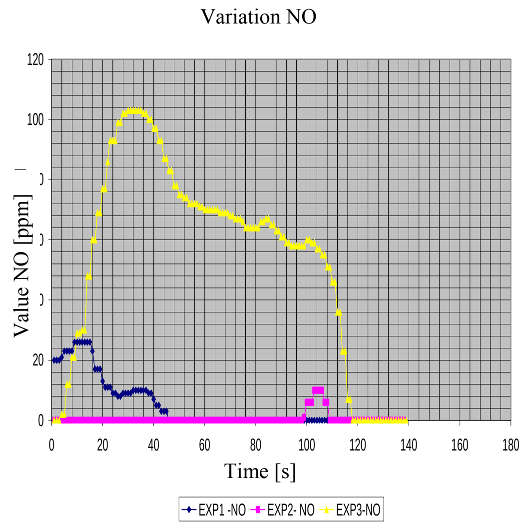

Fig. 6. Variation of NO

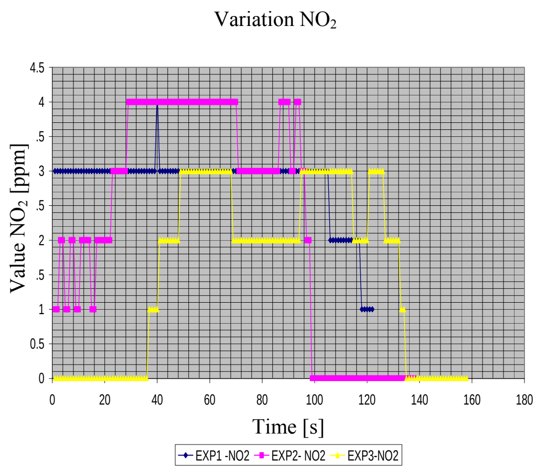

Fig. 7. Variation of NO_2

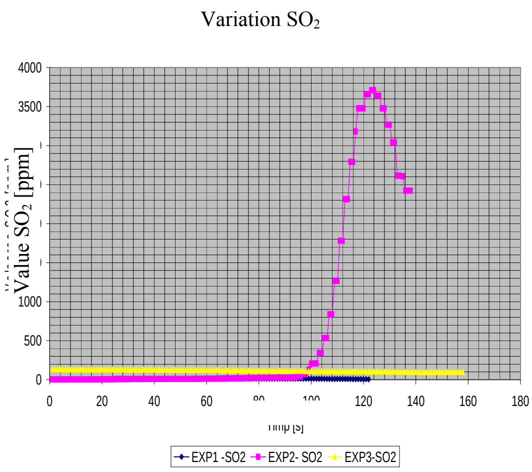

Fig. 8. Variation of SO_2

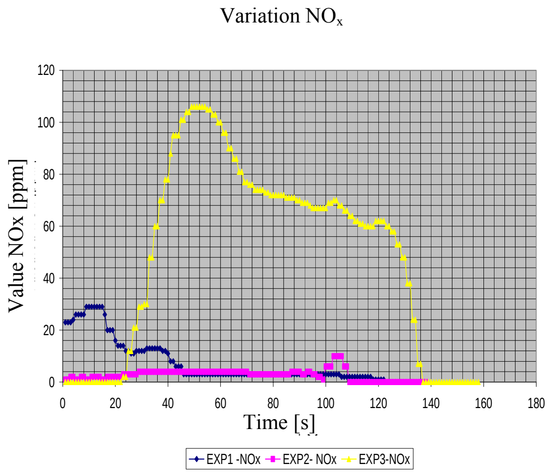

Fig. 9. Variation of NO$_x$

Conclusions

Using the above relations and the experimental results obtained, it was found that:

- The biggest pollution factor C_p max = 77.772 was obtained flame normal;
- The lowest coefficient of pollution C_p min = 24.402 was obtained for reducing use;
- The highest concentration of carbon monoxide COmax = 512 ppm, was recorded in the use of reducing flame;
- The lowest concentration of carbon monoxide COmin = 160 ppm, when used normal flame;
- The highest concentration of nitrogen oxide NOmax = 103 ppm, was recorded in the use of oxidizing flame;
- The lowest concentration of nitrogen oxide NOmin = 10 ppm, when used as the reducing flame;
- The highest concentration of nitrogen dioxide NO_2max = 4 ppm, was recorded for normal use and reducing flame;
- The largest concentration of SOmax = 3711 ppm, was recorded in the use of reducing flame;
- SOmin lowest concentration = 14 ppm when using normal flame;
- H_2S was detected only when using normal flame.

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Contribuţii teoretice şi experimentale privind poluarea mediului prin procedeul de sudare cu flacăra oxi - gaz (SF)

Rezumat

În lucrarea de faţă sunt prezentate cercetarile efectuate in vederea evidentierii tipurilor de substanţe nocive rezultate în urma sudării cu flacără (SF), precum şi valorile coeficientului de poluare total si variatia acestuia cu parametrii regimului de sudare.