Gh. AMZA, D. DOBROTĂ, M. GROZA DRAGOMIR, S. PAISE, Z. APOSTOLESCU

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RESEARCH ON ENVIRONMENTAL IMPACT ASSESSMENT OF FLAME OXYACETYLENE WELDING PROCESSES

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This paper presents the factors that may cause pollution of the work environment when working with the oxyacetylene flame welding process. Experiments were performed using an oven that allows the analysis of all gases resulted in the welding process, but also enables their monitoring using a video camera, and the resulting film was processed in that the frames for each second of experimentation were extracted. The materials used in the experiments were S235JR steel as the base material, and as filler materials, E70S. In order to assess the impact on the work environment of this welding process, the pollution coefficient C_p was defined based on the equation of the material balance.

Key words: gas flame welding, work environment, monitoring, material balance, pollution coefficient

INTRODUCTION

Most welding processes, by their operation mode and the technological equipment used, have a major impact on the environment and pollution is not in the least negligible [1, 2]. Pollution of the environment in which a welding process is carried out, or in which a welded construction is realized is the result of the following characteristics of the technological welding process: it requires an energetic agent that develops the heat required to bring to molten state, or plastic flow of the surfaces of the materials to be welded, which are in contact, heat that is released into the environment in a high percentage that varies depending on the welding process [3]; it requires a number of materials that, by melting, give rise to a multitude of chemical reactions, the result of which is a large amount of gas, most of which are harmful for the environment, if they exceed the maximum permissible concentration; it requires technological equipments which, by their construction and operation, use energy and mineral or organic substances, and which, following exploitation, become harmful for the environment (protective gases, cooling water, oils, grease and protective substances etc.); it requires many auxiliary materials, either to carry out the process or for the realization of the welded joint, either for the desired structural changes in the welded joints, materials which by melting give rise to various chemical reactions or which accelerate certain processes; the technological welding process is made up of a series of powerful polluting auxiliary operations (cutting, preparing the rest of the joint, cleaning, heat treatments, trials and testing, corrosion protection, etc.); some demanding welded joints require post-weld thermal treatments or control by penetrating radiation, which is another major source of pollution; following the technological welding process, a series of waste products result, some having a different and undesirable impact on the work or natural environment [4].

In the category of welding processes that can cause environmental pollution to also fall the gas flame welding. Gas flame welding has as heat source a flame obtained by lighting the gas mixture consisting of the fuel gas, acetylene and oxygen, leaving a burner. In the case of this welding process there are a series of chemical reactions due to the presence of acetylene, resulting in a large amount of gases that have a different impact on the working environment [5].

The main polluting factors generated by the welding technological processes are: the powder and micropowder of different substances with sizes between 1-7µm and lower sizes by 2µm; the particles of heavy metals: Cu, Sn, Mn, Si, Ni, Sb, V, Zn etc.; carbon oxides: CO, CO_2, CO_x; nitrogen oxides: NO, NO_2, NO_x; sulfur oxides: SO_2, SO_3, SO_x; hydrogen sulfide H_2S; acid aerosols: Cl, F, SO_4, NO_3; tropospheric ozone: O_3; volatile organic compounds; saturated hydrocarbons, chlorates, acetones etc.; the persistent organic pollutants: trichlorethan, tetrachlorethilene, trichlorbenzene, xylene, aromatic hydrocarbons etc.; powder; fumes and fog; solid debris (electrode ends, wires, bars, pipes, profiles, slag) [6]. The resulting gases for gas welding flame (oxyacetylene flame) and which pollute the working environment are: CO, NO, NO_2, SO_2, H_2S, NO_x [7].

MATERIALS

In order to achieve the experimental research, three sets of experiments were conducted, depending on the

Gh. Amza, M. Groza Dragomir, S. Paise, Z. Apostolescu Engineering and Tehnological Systems Management Faculty, Polytehnica University of Bucharest, Romania, D. Dobrotă, Engineering Faculty, University "Constantin Brâncuşi" of Târgu-Jiu, Romania

type of flame used in the oxyacetylene flame welding. Thus, depending on the O_2/C_2H_2 ratio, the oxyacetylene flame can be carbonizing, neutral or oxidizing.

The neutral flame is often used for welding and cutting. The welder uses the neutral flame as the starting point, to facilitate obtaining other types of flames. This flame is attained when, by slightly opening the oxygen valve, only two zones of the flame are visible; at this point, the acetylene is being completely burned in the welding oxygen and surrounding air.

The flame is chemically neutral. The two parts of the flame are: the inner cone of the flame which is light blue and the outer cone of the flame, which is dark blue. The inner cone of the flame is where the oxygen and the acetylene combine; this spot is the hottest part of the flame, with a temperature of about 3 300 ^{0}C.

Carbonizing flame occurs when an excess of acetylene causes the carbonization of the flame. This type of flame is characterized by three flame zones: the inner cone of the flame, a white hot area "acetylene feather" and the outer cone. This type of flame is observed when oxygen is first added to the burning acetylene. The unburned carbon insulates the flame and drops its combustion temperature up to 2 760 ^{0}C.

The oxidizing flame is the third type of flame which can be obtained. This type of flame is obtained when the welder adds a larger amount of oxygen to the neutral flame. This type of flame develops a higher combustion temperature than the other two types. It is called oxidizing flame because of the effect it has on the material. The oxidizing flame creates undesirable oxides on most metals.

To achieve the experiments, we have chosen S235JR steel plate as the base material, whose chemical composition is shown in Table 1.

Table 1 **Chemical composition of steel S235JR (the sample liquid steel) / %**

Simbolization	Chemical composition					
	C	Mn	Si	S	P	Other elements
S235JR	max. 0,17	1,4	max. 0,30	max. 0,045	max. 0,045	N=0,09

Regarding the filler material used has, we have employed E70S in the form of wire, whose chemical composition is shown in Table 2.

Table 2 **Chemical composition of wire E70S / %**

Simbolization	Standard	Chemical composition		
		C	Mn	Si
E70S	AWS A5.18-93	max. 0,17	1,40	max. 0,30

Regarding some initial information of the welding process they are shown in Table 3, and these are specific to the 3 types of experiments performed.

The parameters of the welding regime when welding with oxyacetylene flame were adjusted during the experiments depending on the type of flame used during

Table 3 **Initial information on the process of welding oxyacetylene flame**

Filler material	The total mass of the wire / g	Piece mass / g	Debit C_2H_2 / m^3/h	Debit O_2 / m^3/h	Type flame
Wire E70S	10	614	0,15	0,15	neutral
Wire E70S	10	616	0,15	0,175	carbonizing
Wire E70S	10	622	0,2	0,175	oxidizing

Table 4 **Regime of welding parameters welding oxyacetylene flame**

No.	Filler material	t_s / s	Lc / mm	v_s / mm/s	Total mass after deposition / g	Weld metal/ g
1	Wire E70S	73	40	0,55	616	2
2	Wire E70S	61	45	0,74	622	6
3	Wire E70S	73	65	0,89	626	4

Table 5 **Preheating times used in experiments**

No.	Filler material	Type flame	Preheating time / s
1	Wire E70S	neutral	23
2	Wire E70S	carbonizing	36
3	Wire 70S	oxidizing	22

welding, that is, namely, the welding time t_s, the welding seam L_c and the welding speed v_s, and all these values are presented in Table 4. Depending on the welding parameters set, different amounts of debited metal were obtained.

Before starting the welding process, it was necessary to conduct a preheating, and thus the preheating times were determined according to the type of flame used, and their values are presented in Table 5.

RESULTS AND DISCUSSION

In order to assess the environmental impact of the welding process with oxyacetylene flame, the pollution coefficient C_p was defined by the relationship:

$$C_p=M_t/M_{def} \tag{1}$$

where: M_t is the total mass of materials used in the welding process, expressed in g; M_{def} is the mass of the material deposited in the weld seam, in g

The total mass of the material used Mt is determined by the relationship:

$$M_t=M_S+M_{C2H2}+M_{O2}+M_{paer}+M_{ps}+M_{pn} \tag{2}$$

where: M_s is the mass of the wire constituting the filler material; M_{C2H2} – the mass of the acetylene remaining outside the reaction in the welding bath, M_{O2} - the mass of the oxygen released into the atmosphere; M_{paer} the mass of the losses in the air; M_{ps} - the mass of the losses in the soil M_{pn} - the mass of undetectable losses.

The mass of the losses in the air M_{paer} is the mass of all substances released into the atmosphere, which is determined by the relationship:

$$M_{paer}=M_{CO}+M_{H2}+M_{NO2}+M_{NO}+M_{SO2}+M_{H2S}+M_{NOX} \quad (3)$$

where: M_{CO} id the CO mass, released into the atmosphere; M_{NO2} – the mass of NO_2, released into the atmosphere; M_{NO} - the mass of NO, released into the atmosphere; M_{SO2} - the mass of SO_2, released into the atmosphere; M_{H2S} - the mass of H_2S, released into the atmosphere; M_{NOX}- the mass of other nitrogen oxides, released into the atmosphere.

The mass of the losses in the soil M_{ps} is determined by the relationship:

$$M_{ps}=M_{sm}+M_{Z}+M_{sn}+M_{pnd} \quad (4)$$

where: M_{sm} is the mass of potential drops falling on the ground; M_z - is the mass of the slag fallen to the ground; M_{pnd} - the mass of undetectable losses, but which depends on the parameters of the welding process.

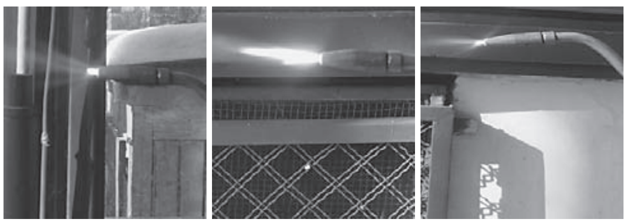
Experimentally, it has been established that M_{pnd} can be calculated with the following relation:

$$M_{pnd}=(0,05...0,06)M_{CO} \quad (5)$$

In the experiments we used an oven which was designed and built so that the types and quantities of gases resulting from welding with oxyacetylene flame could be determined, and different types of flames shown in Figure 1 were used, corresponding to the 3 experiments, and Figure 2 shows a sample obtained after depositing a filler material on a plate piece.

The three different experiments performed required different gas consumption, and in Table 6 are shown the quantities of gases such as C_2H_2 and O_2 consumed during each experiment.

To achieve its objectives, in determining the nature and quantities of welding gases resulting from these processes, the experiment was focused on two research directions: filling the seams and recording the data; quantification of the results and developing models of interpretation.



a b c

Figure 1 Types of flames used: a – neutral – experiment 1; b – carbonizing – experiment 2; c – oxidizing – experiment 3.

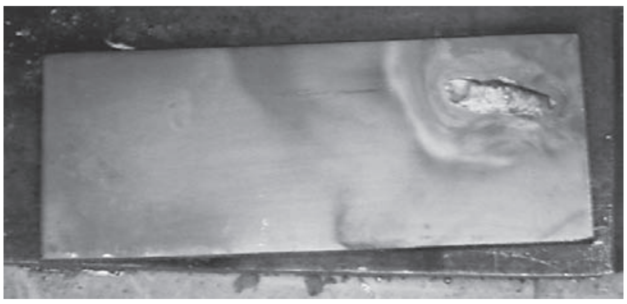


Figure 2 The weld is obtained in experiment 1 (normal flame)

Table 6 **Gas mass of consumed**

No.	Density C_2H_2 / g/m^3	Density O_2 / g/m^3	Consumption C_2H_2 / g	Consumption O_2 / g	Total / g
1	1095	1429	33,3062	43,4654	76,771
2	1095	1429	27,8312	42,3738	70,205
3	1095	1429	44,4083	50,7096	95,117

We must also specify that the experiments were recorded using a video camera, and the resulting film was processed in that the frames for each second of the experiment were extracted.

The values obtained for each experiment, for each type of gas recorded by the instrument are shown in Tables 7, 8 and 9.

The quantitative determination of the fumes resulted during the welding process was made using the equip-

Table 7 (extract) **Gases mass released during experiment 1 / ppm**

No. second	Gas quantities					
	CO	NO	NO_2	SO_2	H_2S	NO_X
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 8 (extract) **Gases mass released during experiment 2 / ppm**

No. second	Gas quantities					
	CO	NO	NO_2	SO_2	H_2S	NO_X
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	3710	0	0
125	429	0	0	3642	0	0
138	484	0	0	2424	0	0

Table 9 (extract) **Gases mass released during experiment 3 / ppm**

No. second	Gas quantities					
	CO	NO	NO_2	SO_2	H_2S	NO_X
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

ment MADUR GA40 PLUS. This equipment is controlled by a microprocessor, has an LCD and a keypad, which make it easy to use and a memory that allow the storage of large amounts of information. The device allows computer connection and the retrieval of information in real time, and the data obtained are processed using a specialized software called "STATISTICA". The quantities of gas found in the experimental research have different values, but from the analysis of the data presented in Tables 7-9, certain experiences were identified which generate the maximum amount of gases released, and the results obtained are shown in Table 10.

Using the relationship 1 and the results presented in Tables 7-9, we were able to determine the pollution coefficient, and the results obtained of the pollution coefficient Cp, for the values corresponding to a second of the experiment are shown in Table 11.

Table 10 **Maximum values of gas detected during experiments**

Gases emitted	quantities of gas emitted / g	Time / s	Experiment
CO	160	90	Experiment 1
	512	133	Experiment 2
	311	123	Experiment 3
NO	26	9	Experiment 1
	10	103	Experiment 2
	103	49	Experiment 3
NO_2	4	40	Experiment 1
	4	29	Experiment 2
	3	49	Experiment 3
SO_2	14	81	Experiment 1
	3711	123	Experiment 2
	135	1	Experiment 3
H_2S	1	1	Experiment 1
	0	-	Experiment 2
	0	-	Experiment 3
NO_X	29	13	Experiment 1
	10	103	Experiment 2
	106	49	Experiment 3

Table 11 **Pollution coefficient values oxyacetylene welding flame**

No.	Mt_{ef} / g	CO / ppm	NO / ppm	NO_2 / ppm	NO_x / ppm	SO_2 / ppm	H_2S / ppm	H_2 /ppm	Mpaer / g	Cp
1	79	111	0	4	4	15	0	0	1,41	77,77
2	76	347	0	0	0	3658	0	0	42,20	24,40
3	99	182	83	3	86	124	0	0	5,04	48,55

CONCLUSION

Using the relations 1-5 and the experimental results we have established the following conclusions:

- the highest pollution coefficient Cp max =77,772, was obtained for the normal flame;
- the lowest pollution coefficient Cp min=24,402, was obtained when using the reducing flame;
- the highest concentration of carbon monoxide COmax=512 ppm, was recorded when using the reducing flame;
- the lowest concentration of carbon monoxide COmin=160 ppm, was established when using the normal flame;
- the highest concentration of nitric oxide NOmax= 103 ppm, was recorded when using the oxidizing flame;
- the lowest concentration of nitric oxide NOmin=10 ppm, was established when using the reducing flame;
- the highest concentration of nitrogen dioxide NO_2max=4 ppm , was recorded when using the reducing and the normal flame;
- the highest concentration of SOmax=3711 ppm, was recorded when using the reducing flame;
- the lowest concentration of SOmin=14 ppm, was determined when using the normal flame.

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