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THEORETICAL AND EXPERIMENTAL CONTRIBUTIONS REGARDING THE IMPACT ON WORK ENVIRONMENT OF WELDING PROCESSES IN MIG / MAG PROTECTIVE GAS MEDIUM

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This paper presents the main factors that cause environmental pollution in the case of the welding procedure in a protective gas environment. In the research the MIG and MAG welding processes were taken into account. The materials used in the experiments were 8TiCr170 stainless steel as the base material and as filler materials 4 types of welding wires were used, characterized by different chemical compositions. To assess the impact on the work environment of such welding processes the pollution coefficient C_p was defined based on the material balance equation as the ratio of the mass of all materials used in the welding process M_t and the effective mass of the welded performed M_u.

Key words: welding, protective gases, work environment, material balance, pollution coefficient.

INTRODUCTION

The use of welded structures has become increasingly present over the last two decades due to the advantages they have in comparison with other structures obtained by other technological processes [1-2]. Determining the environmental impact of the process of welding in the protective gas environment is a complex problem, which requires many years of experiments under different conditions and in different situations. The most important impact of the process is on the working environment, as well as on the welding operators and auxiliary operators in that department, so, the experiments included in the present study allowed to determine that impact. Most welding processes, by the operation and technological equipment with which they are realized, have a major impact on the environment and pollution is not negligible [3].

The main sources of environmental pollution caused by welding processes are electric discharges, electromagnetic radiation, powders, micro powders, fumes, gases of different types and different concentrations, fog, photochemical pollution, dusts, relative organic compounds, heavy metals, decomposition of combustible materials and minerals, waste and industrial waste etc. [4].

In recent decades, specialized enterprises have appeared producing welded construction elements or large welded constructions. Welded Construction Enterprises are based on the process of welding done by different welding processes. These production sites feature a number of technological equipment for welding and other auxiliary technological equipment (for cutting, joint preparation, for cleaning, pickling and degreasing, corrosion protection, trials and testing etc.). And the environmental impact is essential in designing technological process of achieving the welded construction [5-6].

The environmental impact of a welding process can be analyzed in two ways, namely: the impact on the working environment, which is the indoor environment in which the welders and workers who participate in the general technological process operate (health and its evolution); the impact on the natural environment, which is the external environment in which the industrial organization of welded constructions has an influence by means of the substances occurring in the manufacturing process [7-8]. 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, xylene, aromatic hydrocarbons etc.; powder; fumes and fog; solid debris (electrode ends, wires, bars, pipes, profiles, slag). [9-10].

MATERIALS

The input about the basic material and the steps needed to achieve environmental experiments for weld-

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ing in a protective gas environment MIG / MAG was chosen so as to determine by comparison the nature of cases occurring and the quantities of gas and micro particles/particles arising from the application of the welding process.

For a relevant and comparative analysis, numerous experiments were performed by going through the following steps:

- choice of the base material subject to experiments. The basic materials on which the deposits were made was a steel from the class of stainless steels, type 8TiCr170;
- stablishing the methods for cleaning, degreasing and etching on the surface so that where the welding filler will be added there aren't any impurities;
- choice of filler material.

The filler materials were chosen so as to allow a quantitative and qualitative comparison of results;

- determining the main parameters of deposition by welding technology;
- comparative analysis of the results obtained;
- determination of the coefficient of pollution and environmental quality indicator.

The basic material onto which the weld seams for experiments were deposited was 8TiCr170 steel, a ferritic stainless steel, whose chemical composition is shown in Table 1.

Table 1 **Chemical composition of steel 8TiCr170/ %**

Material	Chemical elements			
	C	Cr	Si	Mn
8TiCr170	0,09	16,5	1,0	1,0

In order to conduct experiments to determine the quantities and types of gases resulting from burning different types of filler materials used for the welding in protective gas environment was chosen one of 4 types of filler wire whose composition is presented in Tables 2-5.

Table 2 **Chemical composition of filler material ER70S-6 / %**

Material	Chemical elements		
	C max.	Mn	Si
ER70S-6	0,09	1,53	0,92

Table 3 **Chemical composition of filler material ER70S-3 / %**

Material	Chemical elements		
	C max.	Mn	Si
ER70S-3	0.1	1,1	0,6

Table 4 **Chemical composition of filler material E70C-6M / %**

Material	Chemical elements		
	C max.	Mn	Si
E70C-6M	0,06	1,5	0,6

Table 5 **Chemical composition of filler material ER 80S-G / %**

Material	Chemical elements			
	C max.	Mn	Si	Mo
ER 80S-G	0,1	1,1	0,7	0.5

Also, we used as protective environment to achieve welded joints Ar for the MIG procedure and Ar+CO2 for the MAG process.

RESULTS AND DISCUSSION

Establishing the impact of the work environment was done using the materials balance equation. Material balance equation, in the case of welding processes in the protective gas environment MIG/MAG, is:

$$M_{el} + M_{gp} = M_{md} + M_{pa} + M_{ps} + M_{pnd} \quad (1)$$

where: M_{el} is the mass of electrode wire used in welding; M_{md} – the mass of the metal or alloy deposited in the welding bead, which is determined by weighing; M_{gp} – protective gas mass, which is known; M_{pa} – mass of the losses in the atmosphere, that includes all the substances released in the welding process, which remain in the atmosphere, determining the relationship:

$$M_{pa} = M_{CO} + M_{CO2} + M_{NO} + M_{NO2} + M_{NOX} + M_{SO2} + \\ + M_{H2S} + M_{H2} + M_{agn} \quad (2)$$

where: M_{CO} is the mass of carbon oxides released into the atmosphere; M_{CO2} - mass of CO_2, released into the atmosphere; M_{NO} mass of NO, released into the atmosphere; M_{NO2} mass of NO_2, released into the atmosphere; M_{NOX} - mass of other nitrogen oxides, released into the atmosphere; M_{SO2}- mass of SO_2, released into the atmosphere; M_{H2S}- mass of H_2S, released into the atmosphere; M_{H2}- mass of H_2, released into the atmosphere; M_{agn} - mass of other undetectable gases, released into the atmosphere and which can be calculated with the equation:

$$M_{agn} = (0,005...0,008)M_{CO} \quad (3)$$

Depending on the nature of the base and filler materials, as well as on the protective gas function, Mps - mass of the soil losses includes all substances deposited on the ground after the welding process, which is calculated by the equation:

$$M_{ps} = M_{mp} + M_{ss} \quad (4)$$

where: M_{mp} este is the mass of the particles and microparticles arising from the welding process and deposited on the soil; M_{ss} – mass of the metal splash leaving the weld bath and deposited to the ground. In the relation (1) there is also M_{pnd}, which is the mass of other undetectable substances, which close the balance equation, and can be calculated with the formula:

$$M_{pnd} = (0,06...0,09)(M_{pa} + M_{ps}) \quad (5)$$

Thus the pollution coefficient C_p was defined as the ratio of the mass of all materials used in the welding process M_t and the effective mass of the welded joint performed M_u meaning:

$$C_p = \frac{M_t}{M_u} \tag{6}$$

The welding system parameters were varied in a wide range of values, to finally be able to optimize the technological process of welding in terms of working environment pollution, Table 6.

To establish dependencies between types and quantities of resulting fumes and welding parameters, we have measured, during the experiments, the following parameters: welding current, welding voltage and welding time. After the conclusion of the experiments we have determined the length of the cord, and based on the computing relationship – the linear energy value was determined for each experiment. The experimental results obtained by variable selection of welding process parameters are presented in Tables 7 and 8. The quantitative determination of the fumes resulting during the welding process was done using the equipment MADUR GA40 PLUS and were processed using specialized software called "STATISTICA". The MADUR GA40 PLUS analyzer is a device that can be endowed with between 2 to 6 sensors able to detect different gas concentrations. What is worth mentioning is the fact that just one nitrogen sensor can detect the following types of gas O_2, CO, NO, CO_2, NO_x, H_2S. The first three of them are directly determined, while the rest of them are directly calculated by the analyzer.

The experimental stand was endowed with various elements enabling us to monitor the welding process, and to completely absorb the welding resulting substances, as follows: in the upper part an opening was built in, enabling the measurement device to be inserted; in order for the welder to monitor the electric arc (especially its stability), we had a small part cut out and replaced with a special piece of glass providing protection against the light of the electric arc; in order to create access for the filler material, the port electrode, the welding pistol and the initiation of the welding process, in the bottom part, the stand was provided with an access system of corresponding dimensions. This area was sealed in order to reduce any potential gas or fume leaks.

The experimental stand was designed to meet the following criteria: material: steel; thickness: 5 mm; additional requirement: air tightness; access to the welding space; maximal dimensions of the welded pieces: 750x300x50mm; maximum weight: 80Kg; predetermined volume; a certain degree of universality enabling the realizing of welding joints by the welded analyzed process. In order to realize the welded seams of sheet metals or thicker profiles we used the welding equipment ESAB-LAF 1250 DC. The power source used for automatic submerged arc welding is a power source for triphase welding, operated by a remote control, designed for increased performance in MIG/MAG procedures. This source was also combined with the ESAB, A2-A6 Process Controller (PEH).

Table 6 **Values regime welding parameters**

Filler material name	Welding parameters regime					
	Is / A	Ua / V	Lc / cm	t / s	Vs / cm/s	El / kJ/cm
ER 70S-6	198	21,0	26	60	0,43	8,6
	212	22,2	26	60	0,43	9,8
	288	24,0	29	60	0,48	12,9
ER70S-3	229	21,2	28	60	0,47	9,4
	246	22,8	27	60	0,45	11,2
	265	24,7	36	60	0,60	9,8
E 70C-6M	200	21,5	28	60	0,47	8,3
	210	22,5	26	60	0,43	9,8
	286	24,0	28	60	0,47	13,2
E80S-G	231	21,0	29	60	0,48	9,0
	252	22,0	27	60	0,45	11,1
	272	24,5	35	60	0,58	10,3

Table 7 **Weight values resulting gas during the welding process / ppm**

Filler material name	CO	NO	NO_2	NO_x	SO_2	H_2S	H_2
ER 70S-6	516	0	0	0	0	1	8
	607	0	0	0	0	1	7
	609	0	0	0	1	1	16
ER70S-3	599	0	0	0	1	1	39
	663	0	0	0	1	1	21
	651	0	0	0	1	1	31
E 70C-6M	516	0	0	0	0	1	5
	607	0	0	0	0	1	7
	609	0	0	0	1	1	16
ER80S-G	599	0	0	0	1	1	39
	663	0	0	0	1	1	21
	651	0	0	0	1	1	31

Table 8 **Pollution coefficient Cp values calculated**

Filler material name	Mt / g	Mu / g	Cp
ER 70S-6	1 556,66	1 286,50	1,21
	1 602,08	1 292,02	1,24
	1 635,85	1 298,39	1,26
ER70S-3	1 636,01	1 288,26	1,27
	1 613,75	1 291,77	1,25
	1 637,62	1 299,79	1,26
E 70C-6M	1 637,46	1 289,34	1,27
	1 577,19	1 282,27	1,23
	1 615,76	1 303,04	1,24
ER80S-G	1 659,02	1 276,17	1,30
	1 727,07	1 298,55	1,33
	1 655,75	1 293,56	1,28

CONCLUSION

Following the experimental results obtained, we can draw the following conclusions

– the highest pollution coefficient C_{pmax} = 1,33, was obtained when using the following parameters : I_s = 252 A; U_a = 22 V; t = 60 s; l_c = 27 cm; v_s = 0,45 cm/s; E_l =

11,1 kJ/cm, electrode E805-6, with rutile coating, diameter of the metal rod DVM = 1,2 mm;

– the lowest pollution coefficient C_{pmin} = 1,21, was obtained when using the following parameters: I_s = 198 A; U_a = 21 V; t= 60 s; l_c = 26 cm; v_s = 0,43 cm/s; E_l = 8,6 kJ/cm, electrode E705-6, without coating, metal rod diameter DVM = 1,2 mm;

– the highest concentration of carbon monoxide CO_{max} = 1215 ppm, was obtained when using the following welding mode: I_s = 193 A; U_a = 24,7 V; t = 60 s; l_c = 25 cm; v_s = 0,42 cm/s; E_l = 10,3 kJ/cm, electrode E715-1M, with rutile coating, diameter of the metal rod DVM = 1,2 mm;

– the lowest concentration of carbon monoxide CO_{min} = 0,16 ppm, was obtained when using the following parameters of the welding regime: I_s = 198A; U_a = 21 V; t = 60 s; l_c = 26 cm; v_s = 0,43 cm/s; E_l = 8,6 kJ/cm, electrode E705-6, without coating, metal rod diameter DVM = 1,2 mm and with electrode E70C-6M;

– the largest amount of hydrogen H_{2max} = 56 ppm, was obtained when using the following parameters of the welding regime: I_s = 195 A; U_a = 24,5 V; t = 60 s; l_c = 26 cm; v_s = 0,43 cm/s; E_l = 9,9 kJ/cm, electrode E715-5M, with base coating, metal rod diameter DVM = 1,2 mm;

– the lowest concentration of hydrogen H_{2min} = 5 ppm, was obtained when using the following welding mode: I_s = 200 A; U_a = 21,5 V; t = 60 s; l_c = 26 cm; v_s = 0,47 cm/s; E_l = 8,3 kJ/cm, electrode E70C-6M, with base coating, metal rod diameter DVM= 1,2 mm;

– in most experiments concentrations of NO, NO_2, NO_x, SO_2 and H_2S were not detected.

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