Environmental Impact in Case of Fillet Welds Rehabilitation for Welded Bridges

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In the case of welded bridges, the largest share from the welded joints categories used, are the fillet welds. These fillet welded joints depending on the geometry seam, are very sensitive to stress concentrators from the intersection between filler and base material. The variable loads to which the bridges are subject and the existence of the stress concentrators, cause fatigue phenomenon and appearance of the failures, below the the yield strength of the material. It is therefore necessary, in order to increase the lifetime of fatigue, after a certain number of load cycles bridges, over 10^6, some fillet weld joints must be rehabilitated by welding. The paper presents the steps of a process of rehabilitation by welding in case of cross welded joints, a process occurring substances and polluting products. With an original stand they were made determinations for the pollutants that occur during the reconditioning process by welding. They were calculated the ratio of pollution and it has been proposed some methods to prevent and reduce the environmental impact of this process. Experimental research undertaken and the results, lead to a substantial reduction in pollution caused by rehabilitation relative to fabrication a new joint.

Keywords: reconditioning, loading, welding, impact, environment, pollution, coefficient.Introducere

It has gone from a initial cross welded joint, with shape and dimensions shown in figure 1, which must be rehabilitated by welding.

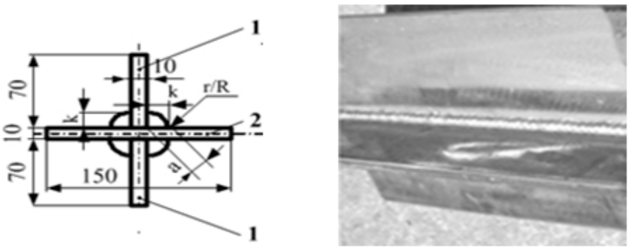

Fig. 1 Initial welded sample

Repairing worn pieces through reconditioning is more complicated than the technology of replacing them with another new piece, but it is particularly efficient and great perspective taking into account present and future trends of development for mankind [1-2]. Reconditioning involves the restoration of worn surfaces of the original dimensions, required by the functional role and to functional features better even than those of the new piece.

Reconditioning, as a technological process has a number of important benefits, including reducing pollution, but in case of loading by welding reconditioning through the environmental impact is not at all neglected [3-6].

The research summarized in this paper aimed to determine the impact on the environment in case of the welding rehabilitation of a cross welded joint.

Experimental part

In order to determine the impact on the working environment and on the natural environment we started from the technological process of reconditioning by welding shown in figures 2 and 3, by analysing in detail each stage with the main polluting by-products and emissions occurring as a result of the process.

For starters, figure 2a shows the convex welding seam which needs welding rehabilitation, because of the stress concentrators placed at intersection between filler and base material.

The notation *e* comes from the fact that we start from an existing seam. In figure 1a, were not noted the size in cross section of the seam, because the rehabilitation technology is applicable for any values of its geometric dimensions. In particular the seam has the apothem a = 5.5 mm and the legs k = 7 mm. In this phase, is done an visual optical control with penetrant liquids for detecting possible non-conformity and their remediation.

In the second phase, as figure 2.b shows, is filed by welding a buffer layer I composed of 7 rows from the existing welding seam and the base material, using low energy linear values, around 0.69 KJ/mm, in accordance with table 1. We use basic coated electrodes E 7018, with the electrode diameter of 2.5 mm. In table 1, there are parameters which indicate the filing regime for buffer layer I.

The electrodes must be with low diffusible hydrogen content of up to 3 ml in 100 g of filler material, in accordance with H4 class. Rows should overlap with 50%.

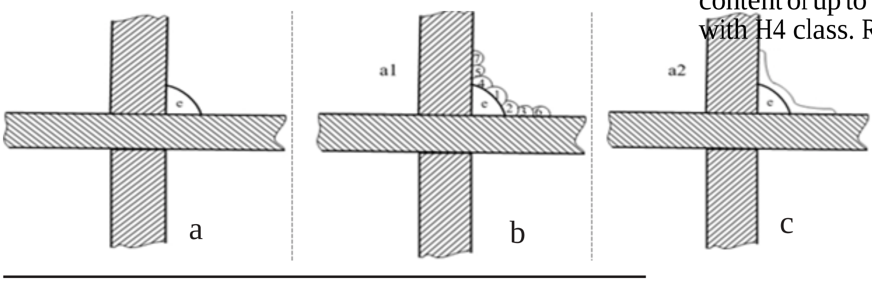

Fig. 2. Presentation of the first three phases of rehabilitation technology a-the existent convex seam; b-buffer layer welding; c-polishing half of the buffer layer

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Table 1
WELDING PROCEDURE PARAMETERS WHEN SUBMITTING THE LAYER I

Row	U [V]	I [A]	Vs [mm/min]	He [Kj/mm]
1	20	100	173	0.69
2	21	95	156	0.76
3	21	95	153	0.79
4	21	95	174	0.66
5	20	95	174	0.63
6	20	95	180	0.63
7	20	95	180	0.59

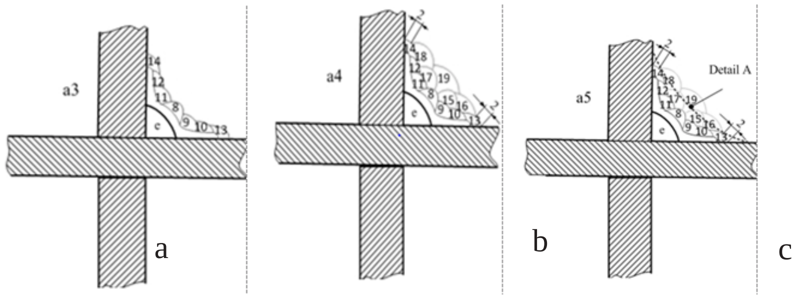

Fig. 3. Presentation of the final phases of rehabilitation technology. a – welding of temper bead layer II, with double linear energy; b – welding the filling layer III; c - polishing half of the filling layer

In the third phase, we remove by polishing half of thickness of the deposited buffer layer with electrodes of diameter 2.5 mm, as shown in figure 2c.

In the fourth phase, as the figure 3.a shows, it is applied by welding the second layer with double value of linear energy, compared to the first, values between 1.38 and 1.44 KJ/mm as the data in table 2 show.

In this case, welding was done with rutile tubular cored wire, with diameter of 1.2 mm, brand: E71T-1MH4 according to the norm AWS A5.20. At the welding of the second layer, this must produce a heat absorption by about 70% higher than in the first layer, such as in the base material will produce a normalization treatment of large grain area, for a reduction of the grain size from 5 to maximum 6.

In phase five, the welding layer III, consisting of 5 rows from 15 to 19, as show in figure 3b, the linear energy has to be almost double to the one introduced in layer II, with values around 2.8 KJ/mm, as in accordance with the data in table 3. We use E 7018 electrodes, with the wire electrode diameter of 4 mm. The electrodes have also low content of diffusible hydrogen, at around 3 mL at 100 g filler material, class H4. In this phase, it is not necessary for the welding rows to overlap. We note that the layer III, can be called the filling layer, because in the sixth phase, will be removed by polishing, aiming to produce the heat treatment for the layer II welded previously and to produce a stress relieving to the cuts of the seams at the intersection between filler and the base material (be sure to respect the quota of 2 mm). Welding rows 16 and 18 must be done at 2 mm inside, from the edge rows 13 and 14. This dimension is one of the most important conditions for success and to increase the fatigue lifetime, as can be seen in figure 3 c. The welding parameters used for the welding of the layer III, are presented in table 3.

After welding layer III, the sixth phase follows, which consists of polishing the weld seam in the concave shape, as shown in figure 4, which is actually an increased scale of detail A, from figure 3 c.

In figure 4, the dotted line represents the line for the polishing, r = 4 mm represents the connection radius between filler and base material, Ra = 1.2μ m, the roughness that the surface should reach. We mention that

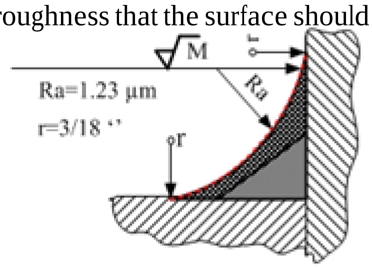

Fig. 4 Concave shape polishing of the rehabilitated seam

Table 2
WELDING PROCEDURE PARAMETERS FOR WELDING OF THE THE LAYER II

Row	U [V]	I [A]	Vs [mm/min]	He [Kj/mm]
8	21	235	208	1.42
9	22	235	224	1.38
10	22	230	212	1.43
11	22	230	210	1.44
12	21	230	201	1.44
13	21	230	202	1.43
14	21	230	207	1.40

Table 3
WELDING PROCEDURE PARAMETERS WHEN SUBMITTING THE LAYER III

Row	U [V]	I [A]	Vs [mm/min]	He [Kj/mm]
15	21	260	124	2.64
16	21	260	117	2.78
17	22	250	117	2.82
18	21	250	117	2.80
19	22	240	119	2.65

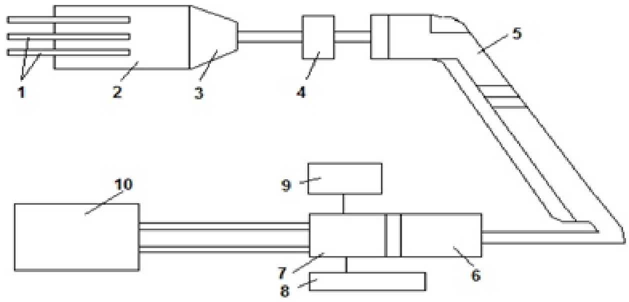

Fig. 5. Principle scheme of the experimental stand used for measurements: 1-sensors; 2-sampling pump; 3-oven; 4-suction pump; 5-handle-actuator; 6-filter elements; 7-element; 8-tank condensation; 9-microcontroller; 10-information display

after polishing, it has been done an visual optical and and with penetrant liquids control, for the detection of possible non-conformance at the conection between the base and filler material. If any defects are detected, they will be fixed using the same technique of temper bead welding TBW.

It makes it more accurate as the phases described above, belong for rehabilitation or reconditioning by welding of a single convex seam of the four existing of the fillet weld, presented in figure 1. The other beads were not drawn, but they exist. Therefore, we recommend that seams reconditioning should be made in parallel respecting all steps described above. Reconditioning is recommended to be made as per phase, applying a phase of each weld seams, the initial order of welding seams being made in the initial order of welding seams, meaning diagonally. In other words, we apply for example phase I (buffer layer welding) at the number 1 seam, then the diagonal for the seam number 3 and then 4 and so on. Only after the implementation of phase I at all seams, we proceed to phase II, and continue till the end, going in parallel with the reconditioning of welded seams.

For an analysis as genuine and accurate determination as to the impact on the environment, it was chosen as a suitable equipment for the intended purpose in accordance with the European standards in force and it has built an experimental original stand, which can be used both for determining the impact of the working environment and on the natural environment, easy to use and to permit a proper valuation as an environmental impact [7, 8].

Measurements were made in accordance with an experimental methodology established pursuant to Order No. 462/MAPPM 93, under conditions of normal operation from the technological point of view.

The principle scheme designed and built by the experimental stand is presented in figure 5.

For the determination of gases resulting from the combustion (CO, CO_2, NO_2, NO_x, SO_2, CH_4 etc.) used an Analyser type MEGALYZER 9600 with standard equipment and equipped with a host of special transductions.

Results and discussions

As was noted in paragraph 2 in order to rehabilitate the cross welded joint, were used manual welding processes with coated electrodes and welded shielding gases.

In order to determine the impact on the working environment and the effects of pollutants on the human operators, based on material balance equation for characteristic cases, experimental results have been obtained which are presented in table 4, for reconditioning by welding using manual arc welding and coated electrodes and in table 5 for reconditioning by welding using shielding gases.

Table 4

EMISSIONS AND POLLUTING BY-PRODUCTS RESULTING FROM RECONDITIONING BY WELDING USING MANUAL ARC WELDING, IN kg/1t WELDING SEAM

No. crt.	Emission or polluting by-products	U.M.	The maximum quantity
1	Dust in the air	Kg/t	18.5
2	CO	Kg/t	275.5
3	CO_2	Kg/t	380.2
4	SO_2	Kg/t	194.3
5	SO_4	Kg/t	87.8
6	NO_x	Kg/t	103.7
7	NH_3	Kg/t	5.9
8	CH_4	Kg/t	-
9	Flue gas (other)	Kg/t	4374.4
10	Heavy metal particles	Kg/t	11.2
11	Cinder	Kg/t	208.5
12	Splash	Kg/t	21.4
13	Filler materials waste	Kg/t	24.6
14	Volatile organic compounds (VOCs)	Kg/t	54.2
15	Vapour	Kg/t	3.4
16	Steam	Kg/t	16.9
17	Dust and oxides	Kg/t	64.2
18	Metallic wastes	Kg/t	82.6
19	Volatile powders	Kg/t	11.4
20	Polycyclic aromatic	Kg/t	2.8
21	Waste solutions (treatments)	Kg/t	394.8
22	Water supply (treatments)	Kg/t	317.5
Total		Kg/t	6652.8

Table 5
EMISSIONS AND POLLUTING BY-PRODUCTS THROUGH WELDING RECONDITIONING USING SHIELDING GASES, EXPRESSED IN kg/1t WELDING SEAM

No. crt.	Emission or polluting by-products	U.M.	The maximum quantity
1	Dust in the air	Kg/t	11.2
2	CO	Kg/t	48.7
3	CO_2	Kg/t	456.9
4	SO_2	Kg/t	87.2
5	SO_4	Kg/t	43.9
6	NO_x	Kg/t	4.6
7	NH_3	Kg/t	-
8	CH_4	Kg/t	-
9	Flue gas (other)	Kg/t	2894.5
10	Heavy metal particles	Kg/t	4.6
11	Cinder	Kg/t	-
12	Splash	Kg/t	7.2
13	Electrode wastes	Kg/t	2.4
14	Volatile organic compounds (VOCs)	Kg/t	26.3
15	Vapour	Kg/t	2.4
16	Steam	Kg/t	-
17	Dust and oxides	Kg/t	48.8
18	Metallic wastes	Kg/t	29.6
19	Volatile powders	Kg/t	9.2
20	Polycyclic aromatic	Kg/t	4.6
21	Hex chlorobenzene	Kg/t	3.8
22	Carcinogens	Kg/t	0.9
23	Dioxins and furans	Kg/t	2.2
24	Waste solutions (treatments)	Kg/t	337.5
25	Water supply (treatments)	Kg/t	450.5
Total		Kg/t	4475.0

The impact on working environment was assessed by calculating the coefficient of pollution with the CPS welding of the form:

$$Cps = (Mtef) / Mue \quad (1)$$

where: Mue is the mass of the material (filler material) that enters into the welded seam, in kg; Mtef - total weight of materials used for the realization of the bead (filler material plus auxiliary materials used) and is calculated according to the relation:

$$Mtef = Mue + Mp \quad (2)$$

where: Mp is the mass of the pollutants that are emitted in the working environment and is calculated according to the relation:

$$Mp = Mpaer + Mps \quad (3)$$

where: Mpaer is the mass of substances that pollute the air, which was calculated by the relation:

$$Mpaer = Mm + MH2 + MCO + MH2S + MCO + MNO + MNO2 + \\ + MH2S + MSO2 + MSO4 + Man \quad (4)$$

where: Mm is the mass micro-particles with the smaller size of 5μm remaining in air or which are submitted after a long time; M_{CO} - CO mass emitted into the atmosphere; MH_2 - mass of H_2, issued in the atmosphere; MNO - NO mass emitted into the atmosphere; MNO_2 - NO_2 mass, issued in the atmosphere; MH_2S - H_2S mass issued in the atmosphere; MSO_2 - mass of SO_2 emitted into the atmosphere; MSO_4 - SO_4 mass, emitted into the atmosphere; Man the mass of other substances undetected emitted to the atmosphere.

The mass of substances that pollute soil Mps was calculated with the relation:

$$Mps = Mpp + Mmp \quad (5)$$

where Mpp is the particle's mass: reaching the ground; Mmp is micro-particles that remain in the atmosphere and are deposited gradually.

In case of reconditioning by welding load in protective gas environment the pollution coefficient of Cps is calculated according to the relation of the form:

$$Cps = (Mtef + Mgp) / Mue \quad (6)$$

where: Mgp is the mass of gas protector used to make the welding seam.

As a result of measurements and calculations done in a single working shift under normal conditions of the technological process, taking samples from each working area, where there are working as welders operators and auxiliary workers, we have found the following:

- the concentrations of inhalable powders containing iron, manganese, chromium, aerosols and puffs of different metals differ vastly according to CMA Order no. 1957/1995 at all investigated working places in different proportions (sometimes even 3.5 times);
- the concentrations of nitrogen oxides and ozone in excess of the CMA under Order No. 1957/1995 at all investigated working places and in different proportions (1.5 ... 2.3 times);
- the carbon oxide concentrations in excess of the CMA under Order No. 1957/1995 at all investigated working places and in different proportions (1.2 ... 2.3 times);
- the concentrations of various powders exceed the value of the CMA according to Order No. 1957/1995, especially in the surface preparation machine for the purpose of reconditioning;
- the sound-level values are between 109.9 and 121.5 dB(a) Leq at the level of preparedness of the lines,

corresponding to the value of 112.5 dB (A) the *n.a.e.c.*, which exceeds the allowed maximum of 87 dB (A) the *n.a.e.c.*, in accordance with the provisions of art. 5 of the G.O. 493/2006, as amended;

Conclusions

There are many parameters of the technological process of reconditioning that affect differently the emission of pollutants into the environment regarding the physical phenomena, chemical, mechanical, electrical and nuclear power stations that appear during the process;

It is hard to set the balance equation of materials for the technological process because the conditions are very different and there is no universal stand for realizing the measurements;

Following the determinations made in various working areas, at the level of the respiratory apparatus were as follows: the amount of inhaled powders concentrations, aerosols and puffs of different metals exceeded the CMA Order no. 1957/1995, in different places and in different proportions; the concentrations of iron oxides, nitrogen oxides and CO exceed the CMA Order No. 1957/1995, for every investigated working jobs in different proportions; and the concentrations of metallic vapour and metallic ions exceed the CMA Order No. 1957/1995 at each working place.

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