A THEORETICAL MODEL FOR ESTIMATING THE EFFECTS OF THE HUMIDITY IN SOME ELECTRODE PASTES ON THE DIFFUSIBLE HYDROGEN IN THE WELD DEPOSIT

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Având în vedere influențele nefavorabile pe care le exercită hidrogenul asupra materialului depus prin sudare, este de mare importanță să se controleze conținutul de hidrogen difuzibil din îmbinarea sudată prin controlul umidității învelişurilor electrozilor. Acest lucru presupune a determina influența umidității învelişurilor electrozilor asupra hidrogenului difuzibil din îmbinarea sudată prin măsurarea acestuia din urmă pe epruvete încărcate prin sudare cu electrozi bazici, care anterior au fost ținuți în camera climaterică şi deci cunoscânduli-se umiditatea din înveliş. Lucrarea îşi propune a determina un model teoretic (matematic) a influneței umidității unor învelişuri bazice asupra hidrogenului difuzibil din îmbinarea sudată. Aceasta deoarece este foarte greu, şi până în momentul de față nu s-au reuşit, de a determina corelația dintre hidrogenul potențial (cantitatea totală de hidrogen prezentă în masa învelişului electrozilor şi cel difuzibil din metalul depus prin sudare.

Taking into account the unfavourable effects the hydrogen has on the weld deposit it is of great importance that the diffusible hydrogen in the welded joint be controlled by checking the humidity in the electrode pastes. This action involves the determination of the effects the humidity in the electrode pastes has on the diffusible hydrogen in the welded joint by measuring the latter on an eprouvette loaded by welding with basic electrodes previously kept in the climate room that is with an already known humidity in the paste. This research study aims at establishing a theoretical model (a mathematical one) for the effects of the humidity in some basic electrode pastes on the diffusible hydrogen in the welded joint. Actually it is very difficult and no one has succeded do far to establish the correlation (the total quantity of hydrogen present in the electrode paste mass) and the diffusible hydrogen in the weld deposit.

Keywords: diffusible hydrogen, theoretical model, electrode, humidity.

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1. Introduction

The main source of diffusible hydrogen in the welded joint incase of electric-arc welding with coated electrodes is represented by the humidity in the electrode coats. This humidity is found in the electrode coat/paste in the form of water absorbed due to the hygroscopic substances in the coat, crystallization water and chemically linked water.

The data presented in the speciality literature show that the main substances responsible for the presence of diffusible hydrogen in the weld deposit are the sodium and potassium silicates. Therefore, 3 types of electrode coats with different contents of sodium and potassium silicate were used for the purpose of measuring.

The measurements focused on two main directions:

- To establish the degree of humidity of the electrode coats for various times of maintaining in certain air conditioning conditions;
- To establish the diffusible hydrogen on samples with electrodes which humidity was previously determined.

Establishing the degree of humidity in the electrode coats required the initial determining conditions to be those shown in the Table 1.

Table 1

Measures	Value
Humidification temperature ,^{0}C	30
Relative Air Humidity, %	70
Electrode diameter, mm	3.25
Calcination temperature before humidification, ^{0}C	250
Calcination time, hrs	2.5
Air movement speed inside the humidification space	Still air

The following three distinct phases werecompleted to establish the diffusible hydrogen:

- Selection of epprouvettes for weld deposit
- Metal deposit by welding with humidified electrodes on the epprouvette;
- Establishment of the diffusable hydrogen in the weld deposit

The results of measuring the humidity in the coat and the diffusible hydrogen are shown in Table 2.

Table 2

Electrode type	Measured	Maintaining time, h					
		0.5	1.0	1.5	2.0	4.0	5.0
Electrode with 100% potssium silicate	Coat humidity, %	0.85	2.05	2.75	2.5	3.22	3.65
	Diffusible hydrogen, cm^3/100g m.d.	7.56	13.06	15.83	17.52	22.25	24.73
Electrode with 100% sodium silicate	Coat humidity, %	0.65	1.35	1.78	1.90	2.42	2.62
	Diffusible hydrogen cm^3/100g m.d.	6.12	9.48	12.03	13.73	17.76	18.72
Electrode with 60% sodium silicate and 40% potassium silicate	Coat humidity, %	0.45	0.82	0.88	0.94	1.20	1.25
	Diffusible hydrogen, cm^3/100g m.d.	3.62	6.03	6.53	6.92	7.56	8.32

2. The establishment of the theoretical model for the corelation between the humidity in the elctrode coats and the diffusible hydrogen

When tracing the variation graphic of the diffusible hydrogen depending on the humidity in the electrode coat we notice a linear dependence between the two magnitudes; at this phase the question of determining a linear relation between the studied values arises. The linear relations for all the three types of electrodes are to be established.

The studied magnitudes shall be marked as follows:

$\tilde{y}_i$ – diffusible hydrogen in cm^3/100g m.d. for i = 1,2,3

(1 - the electrode with 100% potassium silicate; 2 - the electrode with 100% sodium silicate; 3 - the electrode with 60% sodium silicate and 40% potassium silicate)

$\tilde{x}_{ij}$ – coat humidity in [%] for i=1, 2, 3 and j=1, 2, ……, 6

(the 6 measurements for each type of electrode)

If we consider the hypothesis that between the two values x and y there would be a linear relation in the form:

$$\tilde{y}_i = b_{0i} + b_{1i}\tilde{x}i \qquad (1)$$

this relation would be required to be calculated, and after ward the hypothesis be checked whether it is true or not.

The free terms b_{0i} and the angular coefficients b_{1i} are calculated with the equations:

$$b_{1i} = \frac{\sum_{j=1}^{6}(x_{ij} - \bar{x}_i)(y_{ij} - \bar{y}_i)}{\sum_{j=1}^{6}(x_{ij} - \bar{x}_i)^2} \tag{2}$$

$$b_{0i} = \bar{y}_i - b_{1i}\bar{x}_i \tag{3}$$

where $\bar{x}_i$ and $\bar{y}_i$ are calculated with the relations:

$$\bar{x}_i = \frac{\sum_{j=1}^{6} x_{ij}}{6} \tag{4}$$

$$\bar{y}_i = \frac{\sum_{j=1}^{6} y_{ij}}{6} \tag{5}$$

The experimental data in Table 2 were used to calculate the coefficients and then the Tables 3, 4 and 5 were drawn up.

Table 3

x_{yj}			$\bar{x}_i$			y_{ij}			$\bar{y}_i$		
x_{1j}	x_{2j}	x_{3j}	$\bar{x}_1$	$\bar{x}_2$	$\bar{x}_3$	y_{1j}	y_{2j}	y_{3j}	$\bar{y}_1$	$\bar{y}_2$	$\bar{y}_3$
0.85	0.65	0.45	2.42	1.766	0.923	7.56	6.12	3.62	16.825	12.973	6.946
2.05	1.35	0.82	2.42	1.766	0.923	13.06	9.48	6.03	16.825	12.973	6.946
2.25	1.78	0.88	2.42	1.766	0.923	15.83	12.03	6.53	16.825	12.973	6.946
2.50	1.90	0.94	2.42	1.766	0.923	17.52	13.73	6.92	16.825	12.973	6.946
3.22	2.42	1.20	2.42	1.766	0.923	22.25	17.16	7.56	16.825	12.973	6.946
3.65	2.62	1.25	2.42	1.766	0.923	24.73	18.72	8.32	16.825	12.973	6.946

Table 4

$x_{yj} - \bar{x}_i$			$y_{ij} - \bar{y}_j$			$(x_{yj} - \bar{x}_i)^2$		
$x_{1j} - \bar{x}_1$	$x_{2j} - \bar{x}_2$	$x_{3j} - \bar{x}_3$	$y_{1j} - \bar{y}_1$	$y_{2j} - \bar{y}_2$	$y_{3j} - \bar{y}_3$	$(x_{1j} - \bar{x}_1)^2$	$(x_{2j} - \bar{x}_2)^2$	$(x_{3j} - \bar{x}_3)^2$
-1.57	-1.116	-0.473	-9.265	-6.853	-3.326	2.4649	1.2454	0.2237
-0.37	-0.416	-0.103	-3.765	-3.493	-0.916	0.1369	0.17305	0.0106
-0.17	0.014	-0.093	-0.995	-0.943	-0.416	0.0289	0.00019	0.0086
0.08	0.134	0.017	0.695	0.757	-0.026	0.0064	0.179	0.00029
0.80	0.654	0.277	5.425	4.187	0.614	0.64	0.4277	0.0767
1.23	0.854	0.327	7.905	5.747	1.374	1.5129	0.7293	0.1069
				$\sum_{j=1}^{6}(x_{ij} - \bar{x}_i)^2$		**4.7941**	**2.5937**	**0.4268**

The following values of the free terms resulted :

$$b_{01} = \bar{y}_1 - b_{11}\bar{x}_1 = 16.825 - 6.257 \cdot 2.42 = 1.6828$$
$$b_{02} = \bar{y}_2 - b_{12}\bar{x}_2 = 12.973 - 6.39 \cdot 1.766 = 1.688 \quad (6)$$
$$b_{03} = \bar{y}_3 - b_{13}\bar{x}_3 = 6.946 - 5.7059 \cdot 0.923 = 1.679$$

With these calculated coefficients the linear relations become:

$$\tilde{y}_1 = 1.6828 + 6.257 \cdot \tilde{x}_1$$
$$\tilde{y}_2 = 1.6828 + 6.490 \cdot \tilde{x}_2 \quad (7)$$
$$\tilde{y}_3 = 1.679 + 5.7059 \cdot \tilde{x}_3$$

Table 5

$(x_{yj} - \bar{x}_i)(y_{ij} - \bar{y}_j)$				b_{1i}		
$(x_{1j} - \bar{x}_1)(y_{1j} - \bar{y}_1)$		$(x_{2j} - \bar{x}_2)(y_{2j} - \bar{y}_2)$	$(x_{3j} - \bar{x}_3)(y_{3j} - \bar{y}_3)$	b_{11}	b_{12}	b_{13}
14.5460		7.6479	1.5732	6.257	6.39	5.706
1.3930		1.45308	0.19908			
0.0169		-0.0132	0.0386			
0.0556		0.1014	-0.0004			
4.34		2.7382	0.17			
9.7231		4.9079	0.4593			
$\sum_{j=1}^{6}$	**30.0747**	**16.8353**	**2.4353**	**6.257**	**6.39**	**5.706**

The power of the correlation between the *x* group and *y* group is with the relation :

$$R_i^2 = 1 - \frac{n-1}{n-2} \frac{\sum_{j=1}^{6} (y_{ij} - \tilde{y}_i)^2}{\sum_{j=1}^{6} (y_{ij} - \bar{y}_i)^2} \quad (8)$$

where : n=6, number of the tests;

$\tilde{y}_i$ = the y values calculated with the relations (7),

To calculate R_i the table 6 is used and the following values result:

$$R_1^2 = 1 - \frac{5}{4}\frac{2.6745}{93.408} = 0.964$$

$$R_2^2 = 1 - \frac{5}{4}\frac{2.5362}{111.75} = 0.9714 \quad (9)$$

$$R_3^2 = 1 - \frac{5}{4}\frac{0.5441}{14.336} = 0.9525$$

Table 6

y_i			$\widetilde{y}_i$			$(y_i - \widetilde{y}_i)$			$(y_i - \overline{y})^2$		
y_1	y_2	y_3	$\widetilde{y}_1$	$\widetilde{y}_2$	$\widetilde{y}_3$	A	B	C	D	E	F
7.56	6.12	3.62	7.01	5.90	4.24	0.3025	0.046	0.3844	85.84	46.96	11.06
13.06	9.48	6.03	14.51	10.44	6.35	2.1025	0.9216	0.1024	4.17	12.20	0.839
15.83	12.03	6.53	15.32	13.23	6.70	0.0049	1.44	0.0289	0.99	0.8892	0.173
17.53	13.73	6.92	17.32	14.01	7.04	0.0441	0.0784	0.0148	0.483	0.573	0.0006
22.25	17.16	7.56	21.83	17.38	7.62	0.1764	0.0484	0.0036	29.43	17.53	0.3769
24.73	18.72	8.32	24.52	18.68	8.42	0.0441	0.0016	0.01	62.489	33.02	1.887
				$\sum_{j=1}^{6}$		**2.6745**	**2.5362**	**0.5441**	**93.408**	**111.175**	**14.336**

where :

$$A = (y_1 - \widetilde{y}_1)^2$$
$$B = (y_2 - \widetilde{y}_2)^2 \quad (10)$$
$$C = (y_3 - \widetilde{y}_3)^2$$

$$D = (y_1 - \overline{y}_1)^2$$
$$E = (y_2 - \overline{y}_2)^2 \quad (11)$$
$$F = (y_3 - \overline{y}_3)^2$$

The intensity of correlation between x_i and y_i is very closed to unit (>0.9) meaning that this correlation is very intense and the relations show the studied dependency very well.

3. Conclusions

Analysing the calculated mathematical equations we can draw the following conclusions;

a) the equations have approximately the same value, a fact proving that whatever the electrode coat, there is a dependency between the diffusible hydrogen and the humidity in the electrode coat;

b) two directions can be applied as follows:

b.1. when the humidity of an electrode coat is known the diffusble hydrogen introduced in the weld deposit may be established;

b.2 when knowing the diffusible level that may lead to an increasing tendency of cracking at cold, the conditions of maintaining and handling the electrodes may be fixed so that they do not exceed a certain humidity in the electrode code;

c) The relations prove to be useful because it is much easier to establish the coat humidity than the diffusible hydrogen in the welded joint;

d) the fact that the coefficients of the x_i independent variables are high shows that the coat humidity has a rather great influence on the diffusible hydrogen;

e) The relations apply only for electrodes with basic coat because some other types of electrodes involve other significant sources of diffusible hydrogen in the weled joint;

f) If the coat humidity is very low (< 0.4%) the effects of the coat humidity become secondary in comparison with other sources of hydrogen, such as the air humidity in the atmosphere of the electric-arc. It is a proof that this source of diffusible hydrogen should also be taken into account in the welded strongly statically and dynamically stressed structures.

R E F E R E N C E S

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