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STATISTICAL STUDY OF THE INFLUENCE OF ENVIRONMENT ON THE CORROSION OF METALS

The results of a statistical analyses of the effect of three environmental parameters on the corrosion rate of metallic materials are shown. The parameters involved are as follows: sulfur dioxide concentration, chlorides amount in air, and pH of rain water. An analysis of the contribution of each parameter to the corrosion rate of low-carbon steel, copper, and zinc shows that the metal which presents the highest sensibility to acid reaction and sulfur dioxide action is zinc, while the low-carbon steel and the copper present the highest sensibility under the influence of chlorides.

1. INTRODUCTION

On the territory of Galicia, the region in north-west Spain (figure), two thermal power plants are placed. One of them, As Pontes, burns charcoal (lignite) with high sulfur content (5% in dry charcoal). This fact causes an acid precipitation on a restricted area of Galicia which is determined by the prevailing winds from south-west during the greater part of the year. Furthermore, Galicia is a marine region and has a long coast, which means the deposition of a great amounts of chlorides at zones near the sea. Due to the reasons presented, we can say that Galicia can be considered an apppropriate environment to study the influence of these parameters on the corrosion rate of the metals.

As it is well known, the main factors affecting the corrosion rate of metallic materials are the relative humidity and the sulfur dioxide as well as chloride concentrations in the air [1], [2].

The effect of sulfur dioxide content in air on corrosion rate was studied efficiently many years ago for low-carbon steel, copper, and zinc [3], [4], [5]. The changes in corrosion rates of these metals versus the chloride contents in air are also known perfectly [6]. Nevertheless, the bibliography shows only a few papers concerning the effect of pH of rain water on the corrosion of metals. HAAGENRUD [7] studied the effect of pH on the corrosion of low-carbon steel and zinc by means of short-term corrosion test. He concluded that low-carbon steel seems to be influenced by

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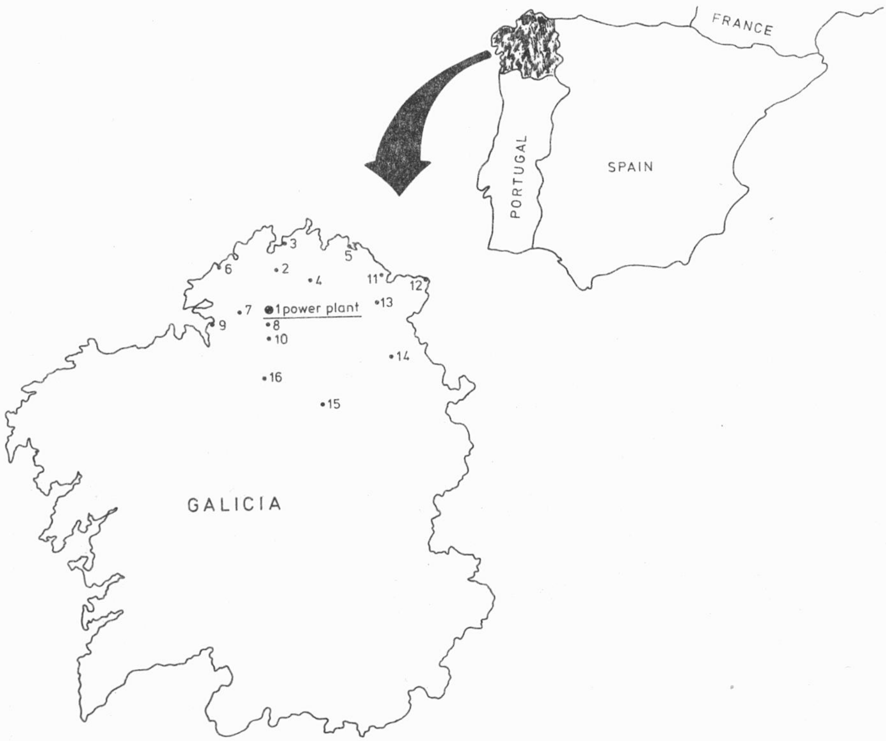

Location of the thermal power plant and corrosion test sites

long-range transport of air pollutants. This phenomenon, however, seems to occur so rarely that the corrosion rates measured for a long time do not seem to be influenced. HAAGENRUD concluded that for zinc the corrosion rate measured once a month and year gave no significant effect.

Because of the above and the special conditions of Galicia, we have designed a research in order to evaluate the influence of environmental parameters on corrosion rate of low-carbon steel, copper, and zinc, as well as we have defined the random character of the effect of the pH or rain water.

2. EXPERIMENTAL

Specimens (100 × 50 × 1 mm) of low-carbon steel (C, 0.096%; Si, 0.183% Mn, 0.350%; P, 0.022%; S, 0.033%; Cr, 0.123%; Ni, 0.161%; Mo, 0.060%; Co, 0.046%; Sn, 0.041%), copper (99.8%), and zinc (99.9%) were exposed to the atmosphere, during two years, in sixteen test sites located around the Thermal Power Plant of As Pontes, at different distances from it (see figure).

We determined the sulfur dioxide concentrations, the deposition rate of chlorides, and the pH of rain water for each test site once a month. The corrosion rates of metals were measured by weight-loss, monthly during the first year of exposure, and each six month during the second year.

Metallographic studies were carried out to evaluate the possible changes of corrosion due to the different pH values of rain water. X-ray diffraction analysis of corrosion products was made to determine their composition.

3. DISCUSSION

The average values of sulfur dioxide contents, chloride amounts, and pH of rain water are presented in tab. 1, and the corrosion rates of the metals are shown in tab. 2.

From experimental data, we calculated statistically the best fitting curves for corrosion rates as the function of environmental parameters and time. The empirical equations, presenting the highest correlations for the three metals, have the form:

$$K = M t^n \alpha$$

where

K – loss of weight (mg per specimen),
t – time of exposure,
M – constant for each metal,
α – term which includes the environmental influence,

$$\alpha = \exp(a|SO_2| + b|NaCl| + c|\Delta pH|)$$

Table 1

The average values of sulfur dioxide and chloride contents, as well as pH of rain water

Test sites	Cl^- (mg NaCl/m^2 day)	SO_2 (mg SO_3/m^2 day)	pH (rain water)
I	11.61	19.75	6.29
II	13.51	23.88	5.25
III	173.86	30.95	5.73
IV	12.27	21.33	6.25
V	50.41	33.12	6.75
VI	35.51	27.90	5.95
VII	19.25	21.19	6.25
VIII	20.75	22.80	6.87
IX	21.95	30.19	5.60
X	16.59	24.86	6.50
XI	22.03	25.04	6.93
XII	21.82	26.22	6.76
XIII	10.26	24.43	7.15
XIV	9.08	22.05	6.73
XV	29.62	35.92	6.45
XVI	7.42	24.31	6.38

Table 2

The average corrosion rates of carbon steel, copper, and zinc

Corrosion rates (mg/dm^2 day)			
Test sites	Carbon steel	Copper	Zinc
I	5.65	0.29	0.23
II	10.20	0.48	0.42
III	16.52	0.79	0.47
IV	11.31	0.40	0.26
V	10.42	0.55	0.26
VI	10.63	0.53	0.74
VIII	9.44	0.42	0.31
VIII	7.75	0.37	0.18
IX	7.16	0.42	0.46
X	8.91	0.33	0.13
XI	8.07	0.21	0.18
XII	6.60	0.42	0.21
XIII	5.43	0.21	0.12
XIV	7.69	0.44	0.27
XV	9.53	0.48	0.30
XVI	4.69	0.32	0.22

where:

$|SO_2|$ – mg SO_3/m^2 day,
$|NACl|$ – mg $NaCl/m^2$ day,
$|\Delta pH|$ = 7, pH of rain water,
a, b, c – constants for each metal.

A statistical study of the contribution of each environmental parameter to the variation of corrosion rates yields the coefficients of contribution presented in tab. 3.

Table 3

Constribution coefficients of metals investigated

Material	Carbon steel	Copper	Zinc
	% contribution		
pH	+10.12	+13.14	+38.88
SO_2	−14.15	+12.41	+58.12
Cl^-	+17.97	+16.45	+ 3.53

4. CONCLUSIONS

The experimental data revealed that zinc is the metal which seems to show the highest variation in its corrosion rate because of changing environmental parameters. The factors that mostly affect the corrosion rate of zinc are the sulfur dioxide concentration and low pH values of rain water. Zinc seems to be also the metal, of the three studied, which presents the highest sensibility to the changes of pH of rain water.

Copper and low-carbon steel do not show a high sensibility to pH variation. They are rather influenced by the variaton of chloride concentration in air.

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STATYSTYCZNE BADANIA WPŁYWU ŚRODOWISKA NA KOROZJĘ METALI

Przedstawiono wyniki analizy statystycznej wpływu trzech parametrów zanieczyszczenia środowiska (stężenie dwutlenku siarki i chlorków, odczyn wody deszczowej) na szybkość korozji metali. Analiza udziału poszczególnych parametrów w procesie korozji niskowęglowej stali, miedzi i cynku wykazała, że cynk jest metalem najbardziej podatnym na szkodliwe działanie dwutlenku siarki i kwaśnego odczynu środowiska. Niskowęglowa stal oraz miedź ulegają korozji przede wszystkim pod wpływem chlorków.

СТАТИСТИЧЕСКИЕ ИССЛЕДОВАНИЯ ВЛИЯНИЯ СРЕДЫ НА КОРРОЗИЮ МЕТАЛЛОВ

Представлены результаты статистического анализа влияния трех параметров загрязнения среды (концентрация двуокиси серы и хлоридов, агент дождевой воды) на быстроту коррозии металлов. Анализ участия отдельных параметров в процессе коррозии низкоуглеродистой стали, меди и цинка обнаружил, что цинк является металлом наиболее податливым к вредному действию двуокиси серы и кислого агента среды. Низкоуглеродистая сталь и медь подвергаются коррозии прежде всего под влиянием хлоридов.