ELECTROCHEMICAL PROPERTIES AND CHARACTERISTICS OF BINARY AND TERNARY ALLOYS OF AL-ZN-MG SYSTEM

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Abstract: *Sacrificial materials are widely used to protect metal structures from electrochemical corrosion. As a base of sacrificial alloys are used aluminum, zinc and magnesium. The article presents the main sacrificial, corrosion and casting properties of binary (Al-Zn, Zn-Mg, Mg-Al) and ternary alloys of Al-Zn-Mg system. The results allow reasonably choose alloy compositions with best electrochemical properties with regard to the operation conditions of cast protectors.*

KEYWORDS: *SACRIFICIAL MATERIALS, ELECTROCHEMICAL PROPERTIES, AL-ZN-MG SYSTEM*

1. *Introduction*

One of the most promising means of combating with corrosion of metal constructions in sea water and soil is electrochemical protection using cast protectors. According to Russian and foreign experience, use of cathodic protection improves technical and economic indicators operated facilities by increasing their service life, reducing the thickness and weight of metal constructions, etc. [1-6].

The role of the sacrificial protection is further enhanced due to the increase in tonnage of ships and the duration of interdocking period of their operation, as well as due to the increase of the tank park of the country and network of main oil and gas pipelines. Sacrificial protection is used for corrosion control of ships and oilfield metallic structures, underground and underwater pipelines, heat exchangers, tanks, reservoirs and other objects. The simplicity and reliability of performance during operation provide to sacrificial protection a high competitive capacity in comparison with other methods of corrosion control.

The possibility of practical use of sacrificial materials for protection of metal constructions against sea and soil corrosion depends on specific properties and characteristics of alloys, existence and condition of paint and varnish coverings and insulating materials, temperature, structure and properties of the corrosion environment and is defined by the following criteria:

- stable on time and the negative potential of alloys low-changing at the wide modes of anode polarization;
- minimum possible and high activity of alloys in electrolytes with various conductivity at the changing external factors, providing set density of current and stable size of protective potential of metal;
- high and stable actual current capacity providing minimum possible unproductive losses of alloys and the greatest service life of protectors. Instead of the actual current capacity often use the coefficient of use efficiency (CUE);
- the minimum tendency of alloys to self-dissolution providing high CUE of protectors and a possibility of their effective application in combination with paint and varnish and insulating coverings;
- the rational form and the sizes of protectors providing the optimum size of current, a zone of protective action and the set service life of sacrificial protection;
- high activity of sacrificial alloys in electrolytes with various conductivity.

Proceeding from the above-noted criteria, specific requirements are imposed to sacrificial alloys, main of which are following: the actual current capacity (Q_η) and the coefficient of use efficiency (CUE) defining service life of protectors; stationary potential (φ_c) and corrosion rate (K) defining corrosion stability of alloys; working potential (φ_n) and the polarizability (P) defining anode activity of material of a protector in relation to the protected construction.

For improvement and stabilization of these properties sacrificial alloys must have the low maximum permissible concentrations of harmful impurity elements, and the cast protectors made on their basis – chemical and structural uniformity.

2. Base metals and alloying components of sacrificial alloys

In agrees to the main criteria and the specific requirements imposed to alloys and cast protectors taking into account their cost, as a basis of sacrificial alloys have found application aluminum, magnesium and zinc [1-4]. These metals have a more negative potential values (Table. 1), than the average potential of the steel construction (-0,35...- 0,44 V).

Table 1. Electrochemical properties of base metals of sacrificial alloys

Metal	Anodic process	Negative potential, V		Current capacity, A·h/kg		CUE, %
		stand.	sea-water	theor.	fact.	
Al	$Al = Al^{3+} + 3e$	1.66	0.56	2980	2500	83
Mg	$Mg = Mg^{2+} + 2e$	2.36	1.40	2200	710	32
Zn	$Zn = Zn^{2+} + 2e$	0.76	0.82	820	800	97

Distinctive feature of sacrificial alloys is the presence at them of Al, Zn and Mg as the main alloying components. The famous grades of sacrificial alloys containing metals bases as the alloying elements have higher in comparison with not alloyed metals technological and operational properties. However these data belong to the areas of sacrificial alloys limited on structure. Lack of comparable data on mutual influence of metals bases of sacrificial alloys in all range of compositions in threefold system (Al-Zn-Mg) doesn't allow establishing nature of this interaction fully. The experience of production and operation of cast protectors which is saved up in recent years has allowed to estimate features of technological processes of their production and to plan ways of improvement of their quality. One of the directions providing improvement of technical and economic indicators of production and application of cast protectors serve not only search of new compositions of alloys, but also complex studying of properties and characteristics of alloys of binary and ternary systems. Complex electrochemical researches of alloys of the Al-Zn-Mg system are of special interest also because there is no information about them in literature.

3. Properties of sacrificial alloys of Al-Mg-Zn system

Below are the main sacrificial (standard and working potentials, CUE, current capacity), corrosive (corrosion rate) and casting (fluidity) properties of the alloys Al-Zn-Mg system. To study of the properties of the alloys were selected compounds belonging to different phase and structural areas of the system. Controllable properties were determined according to the known technological methods and samples [6]. In accordance with the phase diagram of Al-Zn-Mg system for research selected 25 alloy compositions belonging to different phase regions (Table. 2).

Table 2. Chemical compositions of alloys of ternary system, %

Number of alloy	Section	*Al*	*Mg*	*Zn*	Phase area
35	*Zn - T-phase*	0,2	0,2	99,6	γ
36		2,0	3,0	95,0	$\beta + \gamma + \upsilon$
37		4,5	6,0	89,5	$B + \gamma$
38		6,0	8,0	86,0	$B + \upsilon + \eta$
39		8,0	11,0	81,0	$\beta + \eta$
40		9,0	13,0	78,0	$\alpha + \eta$
41		11,0	16,0	73,0	$\alpha + \eta + T$
42		15,0	21,0	64,0	$T + \eta$
43		18,0	23,0	59,0	T
44	*Mg - S-phase*	0,9	97,0	2,1	ε
45		3,0	90,0	7,0	$\varepsilon + S$
46		6,0	80,0	14,0	$\varepsilon + S$
47		10,0	70,0	20,0	$\varepsilon + S$
48		13,0	27,0	60,0	$\varepsilon + S$
49		15,0	50,0	35,0	$\varepsilon + S$
50		20,0	40,0	40,0	S
51	*T-phase -*	48,0	48,0	4,0	δ
52	*$Al_{12}Mg_{17}$*	40,0	40,0	20,0	$T + \delta$
53		32,0	35,0	33,0	$T + \delta$
54		27,0	28,0	45,0	T
55	*Al - T-phase*	24,0	26,0	50,0	T
56		32,0	23,50	44,5	$\alpha + T$
57		60,0	13,0	27,0	$\alpha + T$
58		80,0	7,0	13,0	$\alpha + T$
59		95,0	2,0	3,0	α

Phase diagram of system and alloys compositions shown at Fig. 1. The alloys of defined compositions were prepared using high-purity primary metals: zinc (99.99% Zn), aluminum (99.99% Al), magnesium (99.95% Mg). Preparation of alloys (electric resistance furnace) and cast specimens (metal form), as well as methods of corrosion and electrochemical tests are set out in works [1, 6].

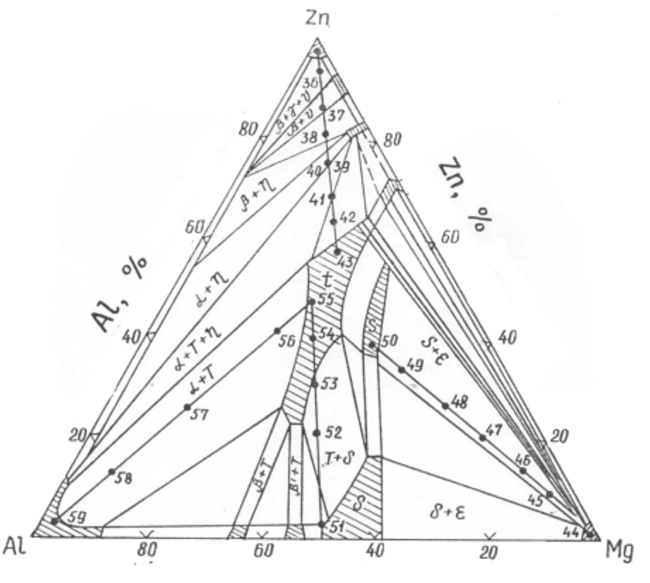

Fig. 1.Ternary system Al-Zn-Mg and alloys compositions (isothermic section at 330°C)

Nine alloy compositions (42,43,49,50,52-56) of the 25 (35-59) were excluded from the control of electrochemical and technological properties, due to their non-technological at the smelting and manufacturing of samples. Alloys rich in magnesium have the highest corrosion rate (0.40 - 0.45 mm / year). Aluminum-zinc alloys with a high content of magnesium, as well as aluminum-rich alloys (58, 59) and zinc-rich alloys (35 - 39) are substantially the same and the minimum corrosion rate (≈ 0.1 mm / year). The negative potential of the stationary alloy ternary system varies from 540 - 600 mV (aluminum angle) 1350 - 1450 mV (magnesium angle). When aluminum doped with zinc and magnesium (58, 59) φ_c increases from -540…-620 to - 680...-750 mV. Introduction of aluminum and zinc in magnesium (44 - 47) leads to a decrease φ_c from -1350...-1450 to -1100…-1200 mV. Alloying of zinc with magnesium and aluminum (35 - 37) practically does not change φ_c, which value is -800…-850 mV. Obviously, depending on the requirements for alloys according to the values of negative stationary potentials in seawater can choose these alloy compositions in a wide range of component concentrations.

Data on the change of the negative potential depending on the alloy composition and the polarization current sample (I = 5 A / m) in seawater. It can be seen that when adding magnesium and zinc in aluminum (58, 59) is an increase φ_n from -470 ... -550 to -700…-720 mV, and when adding of aluminum and zinc in magnesium (44 - 48) φ_n falls from -1100…-1240 to -900…-1000 mV. Zinc alloys (35 - 39) have similar values φ_n equal to -680 ... -710 mV.

Fig. 2 shows the change of CUE of alloys Al-Zn-Mg system depending on their composition. Analysis shows that for zinc alloys (9 – 11.35) CUE reaches maximum values (90-95%); the minimum values of the CUE have the following compositions of magnesium alloys (17-29, 44-48). For aluminum alloys (12; 31-33; 59) CUE reaches 70-75%. It is shown that at high contents of alloying elements in alloys of any basis of the system Al-Zn-Mg is more pronounced heterogeneity of the structure, leading to a decrease in current capacity and CUE.

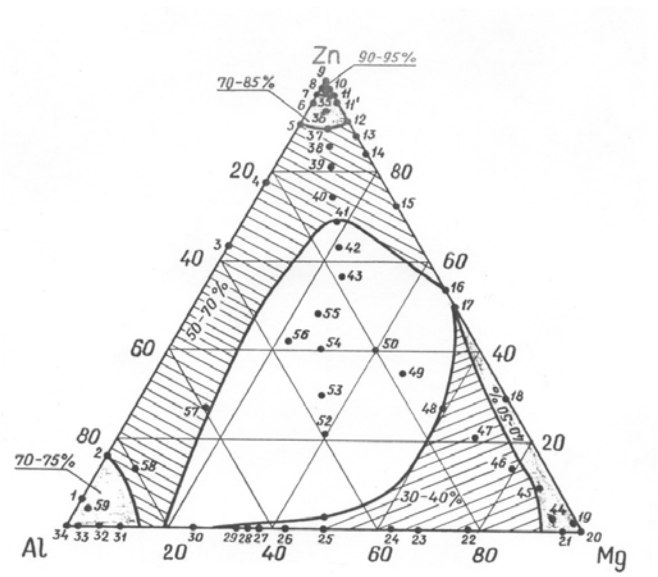

Fig. 2. CUE of Al-Zn-Mg system alloys

4. Conclusions

Analysis of the main electrochemical properties of alloys of Al-Zn-Mg system shows that on combination of corrosion and sacrificial properties low-alloyed alloys should be considered as the best that meet the conditions for the formation of single-phase structures. Depending on the requirements of the sacrificial alloys subject to the conditions of their operation given data allow reasonably choose the alloy compositions in the Al-Zn-Mg system, providing the best electrochemical properties.

5. Literature

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