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Aluminizing as a Reliable Method of Steel Corrosion Protection

Protection anticorrosion efficace à l'aide d'un revêtement d'aluminium

Aluminiumbeschichtung als wirksamer Korrosionsschutz

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SUMMARY

The technology of hot-dip aluminium coating of steel members has been investigated. The corrosion-resisting properties of the obtained coatings have been studied for the areas of industrial and agricultural installations. A favourable effect of alloying of the aluminium melt with manganese on the coating corrosion resisting properties has been shown. Industrial production of aluminium-coated power transmission line supports has been initiated.

RÉSUMÉ

Une technologie a été développée pour le dépôt de revêtements protecteurs en aluminium sur des éléments de structures métalliques par immersion à chaud. Les propriétés anticorrosives des revêtements obtenus sont étudiées dans les milieux agressifs industriels et agricoles. L'alliage d'aluminium fondu avec manganèse exerce une influence positive sur les propriétés anticorrosives des revêtements. La production industrielle des appuis de lignes à haute tension avec revêtement d'aluminium a été mise au point.

ZUSAMMENFASSUNG

Es wurde ein Schmelztauchverfahren zur Herstellung eines Aluminiumschutzüberzugs für Stahlbauelemente entwickelt. Die Korrosionseigenschaften dieses Überzugs in industriellen Medien und beim landwirtschaftlichen Betrieb wurden überprüft. Es wird eine positive Wirkung des Mangans als Legierungselement in Aluminiumschmelzen auf die Korrosionseigenschaften der Überzüge gezeigt. Die fabrikmässige Herstellung aluminiumüberzogener Freileitungsmaste ist aufgenommen worden.

The preservation of structural steelworks of industrial buildings and structures during their service life contributes to decreasing the service labour expenditure and, at present, is one of the major problems.

The total national economy losses due to corrosion of structures under the effects of corrosive atmospheres are approximately 1.5 thousand million roubles per year.

The metal loss, however, is only a part, and not the main one, of the total loss caused by corrosion. It leads to idle standing of equipment, to failures, to drop in equipment capacity and to products quality deterioration.

The continuous intensification of production and increase in capacity of assemblies resulting in a rise of operational effects on structures, on the one hand, and the desire to reduce the structural or building weight by application of thin-walled structures due to the use of progressive designs and high-quality steels, on the other hand, impose additional and more stringent requirements for corrosion protection of metalworks. In this context, the problem of high-durability protective coatings is nowadays one of the most important problems of the national economy.

At present, coatings of zinc, aluminum and their alloys are widely used for protection of structures against atmospheric corrosion and effects of fresh and sea water.

High corrosive resistance of aluminum, fast growth of its production together with the zinc deficiency steady increase raised a question of aluminum coatings wide application in building and industrial production.

One of the most efficient methods of aluminum coating application is hot-dip aluminizing which consists in dipping of a steel product into aluminum melt.

Hot-dip aluminum coatings provide long-term corrosion protection of steel structures in the atmospheres of weak and mean corrosivity (classification according to the Soviet standards). Aluminum coatings 80-100 m thick provide corrosion protection of steelworks for a period of 20 to 50 years, depending on the service conditions.

The increased corrosive resistance of aluminum which is inferior only to titanium in aerated solutions, is accounted for by the resistance of the oxide film consisting of Al_2O_3 or $Al_2O_3 \cdot H_2O$ and appearing on the aluminum surface,

In industrial atmospheres polluted with sulphur compounds, in particular, hydrogen sulphide and sulphurous anhydride, the aluminized steel has a fairly good resistance to corrosion.

It is common knowledge that, in the majority of environments, zinc protects steel electrochemically being an active anode. The problem concerning the possibility of electrolytic protection of steel by means of aluminum coating applied on its surface is not simple. In soft waters, the aluminum coating is considered to behave as a cathodic one, because, in this case, the potential of aluminum is more positive than that of steel. In sea water and in some fresh waters, particularly, when they contain Cl^- and SO_4^{-2}, the potential of aluminum is shifted to more active area, this resulting in polarity reversal of the couple Al-Fe. In these cases, the aluminum coating is an anode and provides a sacrificial protection of steel. One should bear in mind that the couple "base metal" - "protective metal coating" only results from disturbance of the coating (coating defects, porosity of edges after cutting-off).

Service conditions	Corrosivity acc. to Soviet standards	Rate of corrosion, m/year		
		Aluminum coating	Zinc coating	Cm3 without any coating
Urban industrial atmosphere	weak	0.3-0.5	1-3	34-40
Integrated chemical plant	mean	1-3	25-30	200-210
Agricultural installations	weak and mean	5-7	15-20	90-100
Integrated iron-and-steel works	mean	1.5-2.0	25-30	130-140

Table Corrosion resistance of Cm3, zinc and aluminum coatings in different service conditions

Proceeding from the assumption that hot-dip coatings are porousless and that the hot-dip process provides coatings without defects, the aluminum coatings protect the base metal primarily mechanically.

A coating formation takes place when there is an interaction between the liquid phase (aluminum and its alloys) and the solid one (steel surface). At the boundary of these two phases, there occur the processes of wetting, interdiffusion, solution, chemical interaction and crystallization in the system Al-Fe, including some alloying elements. The coatings thus obtained have a complex structure. The layer contiguous with steel consists of intermetallic compounds of Al and Fe, and the surface layer determining the coating durability consists of an aluminum alloy with the inclusions of Fe.

In the course of aluminizing, iron accumulates in the aluminum melt and results in decrease of the coating corrosive resistance, particularly, when its content exceeds 2.5%. The iron concentration exceeding 3.0% (the melt temperature being 700 to 730 C), the crystallization of the intermetallic compound of Fe_xAl_y type occurs on the surface of the product aluminized deteriorating its service properties and appearance.

The optimization of the temperature conditions and of the aluminizing duration allows the iron accumulation in the melt to be reduced, and, thus, the corrosive resistance of coatings to be increased. Another way of increasing the corrosive resistance of coatings is alloying of the melt with elements lowering the melt saturation with iron and neutralizing its adverse effect in the coating.

The full-scale and accelerated corrosion tests of specimens with hot-dip aluminum coatings containing iron, silicon, manganese have shown that hot-dip coatings containing manganese have the greatest durability (Fig. 1).

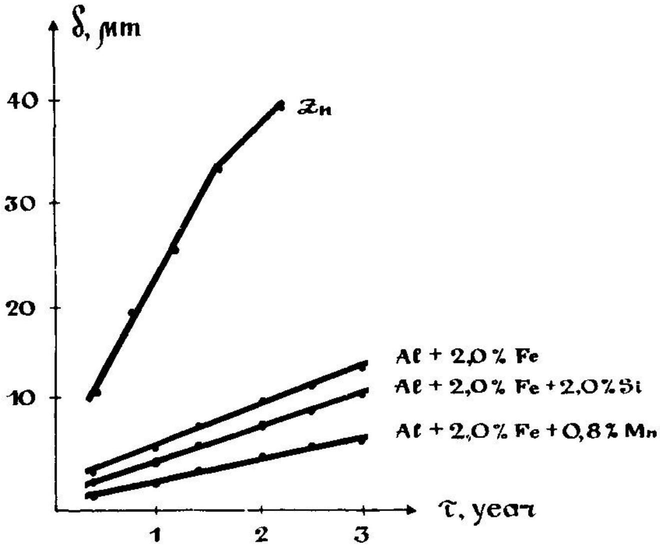

Fig. 1 Dependence of the values of corrosion failure (δ) of aluminum and zinc coatings of steel upon the test period (τ) in conditions of an integrated chemical plant

Alloying of iron-containing aluminum melt with silicon or manganese leads to a change of the electrode potentials of the coating microelements. Manganese neutralizes the effective cathodic action of inclusions $FeAl_3$, whereas silicon forms cathodic inclusions (FeSiAl) and (FeSiAl) in the coating.

The corrosion-resisting properties of aluminum coatings are predetermined by their structure which, in its turn, depends on the conditions of the coating formation. The coating structure is under a great influence of the aluminizing temperature, the steelwork hot-dipping duration, the melt composition and the steelwork cooling conditions after the coating application. Therefore, the observance of technological conditions of aluminizing will allow an aluminum coating to be formed on a steel product surface, this coating having a minimum-thickness intermetallic layer and no cathodic inclusions of $FeAl_3$ and Fe_2Al_5 compounds in the aluminum layer (Fig. 2).

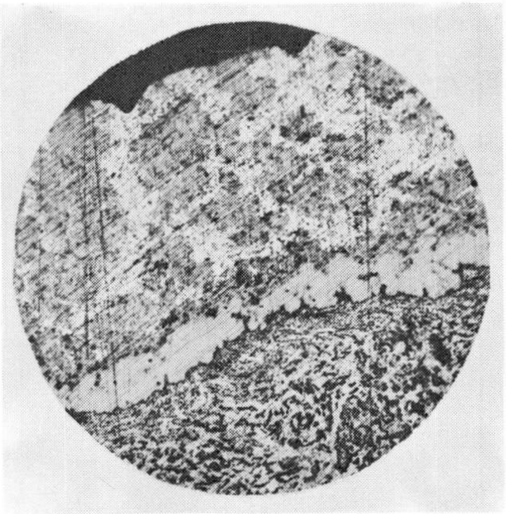

Fig. 2 Aluminum coating microstructure

The aluminizing process has been industrially mastered for corrosion protection of steelworks of power transmission line supports.

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