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PROBLEM OF RESOURCE SAVING WHEN ESTIMATING
A LEVEL OF CORROSION RISK OF PRODUCTION FACILITIES

Y. Vysotsky[1], V. Korolov[2]

[1]Donetsk National Technical University,
[2]Priazovsky State Technical University

Summary

The paper presents technical approaches and specifies procedures to ensure specified service life of steel structures through sustainable use of primary and secondary protection means and methods. Necessity of development of structure of controllable parameters of quality of structures and their coatings corrosion state on the basis of the process approach of the ISO 9001:2000 quality management system is shown. The problem of conformation of compliance of qualitative and quantitative indices of steel structure corrosion protection reliability to the level of building facility corrosion risk is formulated.

Qualitative and quantitative criteria of technological safety, risk levels according to the alternative features including characteristics of vulnerability and threats in the course of steel structure use in corrosion environments are specified. The technique of determination of the primary and secondary protection reliability indices under the specified service life of steel structures is justified. The developed technical approach allows estimating the steel structure availability factor by modeling the corrosion protection reliability indices. The table model of steel structure service life in corrosion environments when maintained according to an actual state is generated for the purpose of control of technological safety parameters in the course of structure use.

The problem of modeling of availability factor under corrosive attack includes a design estimation of steel structure maintainability by the limiting states taking into account corrosion resistance and durability of steel structures and their coatings. Results of physicochemical and mathematical modeling of steel structure availability factor, maintainability indices comparative estimation for specification parameter justification by resource taking into account the intensity of corrosive attacks are presented.

Algorithm of analysis of primary and secondary protection measure efficiency according to requirements of technological safety is developed. The levels of corrosion risk for interval values of availability index of steel structures in corrosive environment are specified. Using the criterion of the corrosion risk provides the possibility of solving the problem of resource saving when choosing the rational measures of the primary and secondary protection taking into account the environment corrosiveness degree and the specified maintenance system.

Introduction

The importance of problem of metal corrosion protection is connected with the release of financial and material resources which are irrationally used for repair of technological equipment, machinery, building structures and constructions due to premature deterioration and reduction of service life in aggressive environments. Duration of structures interrepair time in medium-aggressive and high-aggressive environments makes from 1 to 3 years. Therefore, every 3 years it is necessary to restore the protective coating for 50% of metal structures and to replace 10-20% of structural elements due to corrosion deterioration. According to expert estimates in the Ukraine corrosion loss make 10-15% of all made metal. In 2009 steel making figures were 29.8 million tons and corrosion damage loss could make from 2.9 to 4, and 5 million tons.

In Donetsk region the problem of corrosion is connected with the annual direct expenses of the order of 6,6-7,2 bln. Hrn., 1,3-1,4 bln. Hrn.of which are the losses resulted from the absence of procedural requirements for corrosion risk estimation and the proper use of means and methods of corrosion protection

Expansion of functionalities of metal application in construction, increase of architectural expressiveness of buildings and structures specify the necessity of increasing requirements to means and methods of corrosion protection, including design and technological development of measures of primary and secondary corrosion protection taking into account the set service life of steel structures. It is necessary to note, that the features of metal structure work, character of technological processes, patterns of loadings and composition of corrosive environment exposure influence greatly the parameters of corrosion resistance and durability of structural elements and their protective coatings. Foreign experience evidences that the long-term corrosive failure protection is provided under condition of the agreement with the all parties interested in problems of the specification of corrosion protection [2]. Advantages of development of corrosion failure protection methods on the basis of principles of ISO 9001:2000 quality management are obvious. Successful management and functioning of civil and industrial facilities, transport infrastructure are impossible without additional expenses, their economic efficiency in many respects is specified by a correct choice of constructive and technological approach to corrosion protection.

Increase of steel corrosion resistance, rational choice of constructive approaches, increase in concentration of a material in sections, decrease in influence of internal factors upon initiation of the local, pitting, contact, crevice corrosion, the corrosion cracking, the corrosion fatigue characterize the efficiency of the primary protection measures. The secondary protection provides a restriction or an elimination of the environmental attack on the structure, increases the structure durability when using protective anticorrosive coatings The justification of corrosion protection measures during the building facilities service life reflects the conditions of the estimation of the limiting states and the requirements of assurance of reliability of the structures of buildings and constructions [1].

Principles of quality management

The methodology of the ISO 9001:2000 series standards includes eight principles of the quality management promoting achievement of the purposes for the developed system and organizational structure of management in the course of designing, manufacturing and using of building metal structures. Development of means and methods of the attack protection for maintenance of the set indices of reliability and safety should provide the technical regulation according to the requirements of the customer of constructive and technological measures of the primary and the secondary protection at change of the design situation specified the operational characteristics of the facilities. The policy of the management specifies the purposes of the quality management according to the parameters of the corrosion resistance and the durability, formulated in the target specification for the designing of buildings and structures. Design models of transformation of the requirements of the reliability and the safety into characteristics of using properties of structures specify the methods of monitoring the quality, the diagnostics of the corrosion state, the expediency of involving of the specialized organizations and experts into performance of procedures of the quality conformation. Thus, the quality assurances presented by the specifications of the service life when designing and manufacturing are realized on the basis of the process approach represented as the system of the maintenance service and the repair of structures during the structure stated service life.

The system approach to the management assumes the identification and the formalized description of the stricture stress-strained condition on the basis of the relationship of the "Load-

ing-Structure-Environment" corrosion system. The developed technology of monitoring of the corrosion state provides an opportunity of the estimation of the parameters of regulation of the structure service life for the realization of policy of the constant improvement aimed at up-dating the measures of the primary and the secondary protection. The benefits of the registration method of the estimation of the parameters of the steel structure maintainability according to the actual state allow formulating the approach of the decision-making for the assurance of the technological safety of the structures of buildings and constructions in corrosion environments. It is possible to conclude, that the proposed organizational structure of the mutually beneficial cooperation with suppliers on the basis of principles of the corrosion protection quality management is a basis for the justification of the assured indices of the corrosion resistance and the durability in the course of metal structure manufacturing.

Indices of reliability of primary and secondary corrosion protection according to requirements of limiting state procedure

The sequence of the stages of the technical approach to the management of the means and methods of the steel structure corrosion protection according to the requirements of the technological safety is shown on fig.1. Specifying the requirements to the primary and the secondary protection is made at the coordination with the customer of the typical model of use with reference to which the reliability indices nomenclature is developed. Design development of the manufacture is connected with the analysis of the opportunities of the primary protection at the stage of KM (drawings of metal structures) and requirements for the corrosion resistance in the KMD (drawings of detailed metal structures) working drawings.

When choosing the means of the secondary protection the parameters of the technological rationality connected with the conditions of manufacturing, installation and use are considered. For the justification of the requirements of the corrosion resistance, durability and maintainability the choice of the means of the primary and the secondary protection according to the results of the simulation of the design situations at the structure set service life is made. The steel structure availability factor (Kg) is the complex index of the maintainability characterizing the parameters of the constructive and technological measures of the primary and the secondary protection:

$$K_g = \frac{T_{k\gamma} + T_{z\gamma}}{T_{k\gamma} + nT_{z\gamma}};$$

(1)

where $T_{k\gamma}$ - service life (year) of steel structures according to the parameter of the corrosion resistance (the primary protection); $T_{z\gamma}$ - design service life (year) of protective coats with confidential probability of g=0,95 by the results of the accelerated tests; n - number of repair cycles for renewal of corrosion protection at the specified service life of the facilities.

The comparative analysis of the durability of the corrosion protection of the building structures and constructions is proposed to be carried out according to the developed techniques taking into account the steel structure availability factor (K_g). The problem of determination of the availability factor under the corrosive environment attack (*A,* g/sq.m per year) is formulated as the steel structure design for the corrosion resistance and the durability according to the limiting states by the results of the accelerated corrosion tests.

The purpose of the accelerated corrosion tests is the design estimation of the $T_{z\gamma}$ parameter for the comparative determination of the conformity of the various systems of the protective coatings to the design situations according to the parameters of the corrosion resistance and the durability.
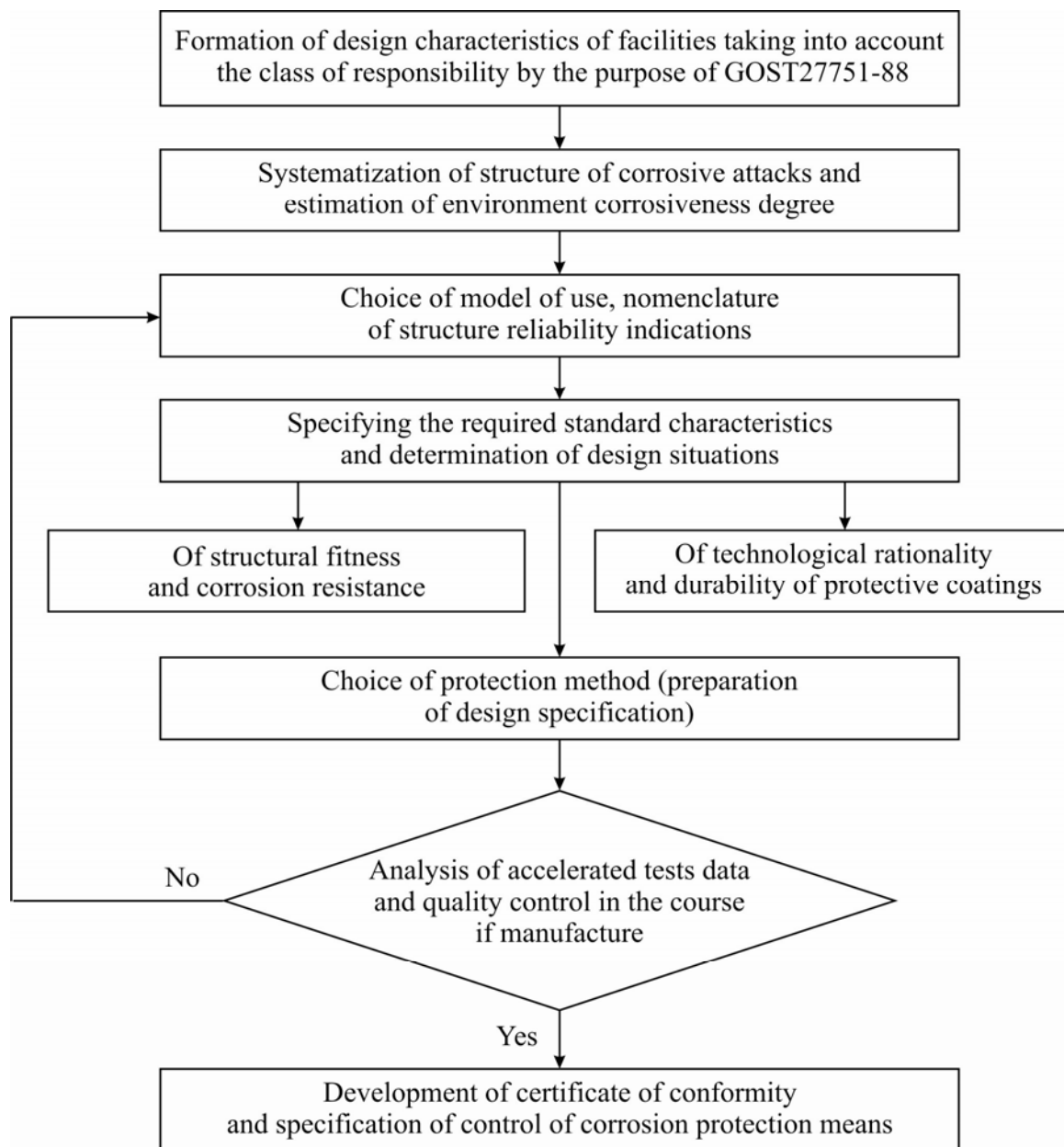
Figure 1 – Sequence of design and technological working off of measures of primary and secondary protection when manufacturing the structures with the guaranteed durability

Estimation of steel structures availability factor in the courseof accelerated tests and according to corrosion state monitoring

The essence of the accelerated test method based on State Standard 9.401-91" ESZKS. "Paint-and-lacquer coating. The general requirements and methods of the accelerated tests for resistance to climatic factors exposure" consists in the effect of the artificial conditions simulating the corrosive attack on samples with the protective coatings. (fig. 2). The sequence of the test carrying out is regulated by the requirements of ICO 129446:1998 standard. Tests of the physic-mechanical and protective properties were carried out on the standard samples. The estimation of

the protective coating properties is made according to the requirements of State Standard 9.407-84.

<center>a)   b)</center>

Figure 2 – The accelerated tests for the corrosion resistance and the durability.
a) The chamber of artificial ageing. b) The chamber of salt fog

The expert estimation of the condition of the overall index of the coating protective properties (A_z) was carried out by means of the relationship:

$$A_z = \sum_{i=1}^{i=N} B_i X_i \qquad (2)$$

where B_i - factor of ponder ability of a kind of destruction; X_i - a relative estimation *of i*-type of failure; i - number of kinds of failure.

The reaction of the resistance to the surface failure [F *(N)*, g per sq.m] is described on the basis of the analytical approach considering the interaction of the parameters of the constructive form *(j)* and the factors of the corrosive attacks *(i)*:

$$\Phi(N) = A_i + A_j + A_{i,j} + A_{i,j-1}; \qquad (3)$$

$$A_{i,j} = a_0 \sum_{i=0}^{i=N} \sum_{j=0}^{j=L} a_{i,j} \Big/ T_k \qquad (4)$$

where $A_{i(j)}$ - system variable of corrosion losses, g/sq.m per year; $a_{i(j)}$ - weight characteristic of parameters of the constructive form (i, j); a_0- corrosion losses of C235 steel (g/sq. m) at duration of the accelerated corrosion tests of 720 hour.; T_k - time interval corresponding to the specified corrosion losses (per year).

Service life of the structure corrosion protection coating (CPC) was specified according to the experimental data of the accelerated corrosion tests by the formula:

$$T_z = \Delta P(N)/A_n \qquad (5)$$

where P (N) - corrosion losses of not protected steel corresponding to the number of cycles of accelerated tests N up to the specified characteristic of failure, g/sq.m; A_n - characteristic value of annual corrosion losses g/sq.m.

Thus, according to the experimental data of the accelerated corrosion tests the statistical estimation of the γ_{zn} reliability factor acceptability constant is carried out and the acceptability constant of the protective coating structure for the determination of the assured durability and maintainability of the designs is specified. The results of the quality control indices are used for making the specification of materials of the structural elements according to the corrosion resistance, durability and maintainability (tab.1).

Table 1. Specification of quality indices by the results of the control of
means of primary and secondary protection in the course of manufacturing

Item	Indication of members of conveyor span, structure materials and protective coats system	INDICATION ACCORDING TO SNIP 2.03.11-85* Surface preparation	Index B_{oz}	Characteristic of using environment corrosiveness A_n, g/sq.m per year)	Service life of structures, covering $T_n/T_{z\gamma}$, year	Availability factor, K_g	Reliability factor, γ_{zn}/γ_{zk}
1	Grade F1, I 30 VSt3sp5, TsBAS №1					0,65	0,93/0,95
2	Grade F1, I 24 VSt3sp5, TsBAS №1	Ia-2 (80) PSt2	4,3	850	50/15,5	0,6	0,93/0,91
3	Grade B1, I 20 VSt3sp5					0,55	0,93/0,88
4	Grade BZ, -220x10, -220x8, 09G2S, TsVAS №1					0.55	0,93/0,90

Monitoring of parameters of corrosion protection quality in the course of use

For the estimation of the properties of the corrosion protection in the course of use the procedure of an audit of the structure corrosion state by means of the F_e parameter of the quality of use specified by the method of G. Taguti was accepted.

The F_e indices of the quality is the relative characteristic of the efficiency of the measures of the primary and the secondary protection for the determination of the risk level according to the (R_i) technological safety taking into account the actual attacks of the factors of the corrosiveness of the structure use conditions. For the determination of the corrosion resistance indices the bench tests of samples of the VCt3pc5 and 09G2C steels, located in conditions of the used facilities were carried out. These tests have corroborated the conformity of the design characteristics of the structure corrosion state and their protective coating to the character and intensity of the environment attack.

The program of monitoring of the corrosion state of span steel structures of conveyor galleries includes the requirements of the DBN V.1.2-5:2007 for the scientific and technical support of building facilities service life (fig. 3).

a)   b)

Figure 3 – Corrosion state for bearing steel structures.
a) appearance of the conveyor galleries of the facilities,
b) corrosion state of the structures and their protective coatings since 8 years of use

The specified methodical approach to the estimation of the efficiency of the measures of the primary and the secondary protection is used for the classification of the KI – KV corrosion risk levels (tab.2).

Table 2. Classification features of level of corrosion risk of structures, buildings and constructions[1]

Degree of corrosiveness attack K, mm per year	Interval estimation of corrosion protection availability factor, K_g				
	$0<K_g \leq 0,1$	$0,1<K_g \leq 0,3$	$0,3<K_g \leq 0,5$	$0,5<K_g \leq 0,7$	$0,7<K_g \leq 1,0$
Weak-level aggressive environment, $0,01<K \leq 0,05$	KI	*	*	*	*
Low-level aggressive environment, $0,05<K \leq 0,15$	KII	KI	*	*	*
Medium-level aggressive environment, $0,15<K \leq 0,30$	KIII	KII	KI	*	*
High-level aggressive environment, $0,30<K \leq 0,50$	KIV	KIII	KII	KI	*
Strong-level aggressive environment, $K>0,50$	KV	KIV	KIII	KII	KI

[1] Note. The sign * designates that for the specified interval values of the (K, K_g) features the level of the corrosion risk is not standardized.

Conclusions

Technical regulation of corrosion problem and development of state policy fundamental principles require justification of the new concept of corrosion protection state program based on principles of strategic crisis management. Application of corrosion risk criterion includes an es-

timation of the condition or situation (threat) which increases the probability of damage due to corrosion failure.

The comparative characteristic of corrosion protection means and methods by the corrosion risk criterion will enable:

- To improve the efficiency of corrosion protection measures and technological safety in the course of designing, manufacturing, using, reconstruction and improvement of buildings and structures.
- To develop the economic approach to corrosion protection quality management on the basis of risk estimation by criteria of corrosion risk.
- To create conditions for innovative development of production facilities for corrosion-resistant materials and protective coatings, to provide the needs of the region in the long-term corrosion protection of structures, buildings and utilities.

Use of the criterion of the corrosion risk provides the possibility of specifying the requirements to the choice of measures of the primary and the secondary protection, and specifies the check standards for the justification of system of the maintenance service and the scientific and technical support of the facilities depending on the environment corrosiveness degree and the corrosion protection availability factor. Thus, conditions for technical regulation of requirements of technological safety at all stages of the structure life cycle, including the development of the system of measures for prevention of emergencies for the facilities of the high corrosion risk danger are created.

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