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BASIC PRINCIPLES FOR CORROSION CONTROL TIPS BASED ON THE ELECTROCHEMICAL CORROSION CELL

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Corrosion control is an important activity of technical, economical, environmental and aesthetical importance. Even though corrosion control principles were established long ago, the practice is not always in accordance with the state-of -the art in this field. So, design procedures seldom contain all necessary steps, i.e. design request, specification of corrosion and other exploitation conditions, selection of materials according to their compatibility, sound design of not only mechanics, but also of geometry and surfaces, maintenance details during the entire exploitation period, etc. Instead some steps are omitted or left to be done by the construction workmanship. In order to elucidate the principles of corrosion control in view of the electrochemical nature of both corrosion process and corrosion protection (CP), a step-by-step procedure is given based on the operation mode of a corrosion cell. In such way, a justification of each CP procedure is made clear.

Key words: corrosion control; design; corrosion cell; electrochemical concept

ЕДНОСТАВНИ ПОСТАПКИ ЗА СПРЕЧУВАЊЕ НА КОРОЗИЈАТА – ПОУКИ БАЗИРАНИ ВРЗ КОНЦЕПТОТ НА ЕЛЕКТРОХЕМИСКА КОРОЗИВНА ЌЕЛИЈА

Заштитата од корозија е важна техничка, економска, еколошка и естетска активност. За жал, без оглед на тоа што законитостите и техничката изведба на постапките воопшто не се нови и непознати, многу често во практиката се случува тие да не бидат (целосно) применети. Така ретко кога во процесот на проектирање на метални структури се застапени сите неопходни зафати како што се, на пример, проектно барање, специфицирање на корозивните и други услови при експлоатација, избор на материјалите според нивната компатибилност, соодветно проектирање не само на механичките туку и на аспектите на геометријата и површината што се важни за заштита од корозија, деталите на одржување во текот на целиот период на експлоатација итн. Дел од овие зафати се занемаруваат или му се препуштаат на изведувачот на заштитата, со сите можни негативни последици. За да се појаснат правилата за заштита од корозија што ја уважуваат електрохемиската природа како на процесот на корозија така и на заштитата од неа, предложена е детална постапка што произлегува од принципот на функционирање на т.н. корозивна ќелија. Со тоа се нуди единствена и заедничка основа на сите постапки за заштита од корозија, базирана на прекинување на струјното коло во корозивната ќелија. На ваков начин на постојните методи за заштита од корозија, познати како: 1) заштита со промена на корозивната средина, 2) заштита со промена на металот што кородира, 3) заштита со промена на електродниот потенцијал и 4) заштита со површински превлеки, им се дава нова смисла, како единствен концепт базиран врз постоењето на корозивна ќелија.

Клучни зборови: заштита од корозија; проектирање; корозивна ќелија; електрохемиски концепт

INTRODUCTION

Proper design is an important part of every corrosion protection (CP) activity, but frequently it does not get the full attention it deserves. The efforts of proper and complete CP design are to be understood as a measure that enables the best corrosion performances, normally in conjunction with accomplishment of other activities. Despite the fact that CP design is based on principles that are rather simple, easy to understand, and well known, some of them are neglected in performing the integral project as a whole.

Proper design of a metallic structure implies a creation of product that is functional, with good mechanical properties, easy to produce, use and maintain for a requested period of time, at low costs, etc. Unfortunately, as far as the corrosion protection aspect of design is concerned, it often does not get the due attention. The statement that corrosion protection begins at the constructor's desk [1, 2], no matter how many times quoted in corrosion protection textbooks, is seldom fully applied in designing practice [3]. Designs that start up with design criteria and contain precise description of corrosion relevant conditions during the entire exploitation period, as well as consider the choice of materials and their compatibility, followed by corrosion protection aspect of every design step (as, e.g. mechanics, geometry, surfaces, etc. [4, 5]), comparison of alternative construction solutions, and end with structure's lifelong maintenance, are rather rare in practice, to the best of these authors' knowledge. Instead, this important task is frequently leaved over to the structure's erector who may be properly qualified and motivated to do it, but will not necessarily execute it.

On the other hand, principles underlying the corrosion control are rather simple, understandable, and more or less familiar to metallic structures designers. Notwithstanding, they are not fully applied, and sometimes even neglected. This dichotomy in corrosion design's theory and practice deserves our attention. This paper is aimed to add some more arguments in favor of proper corrosion design, by depicturing the principles from another point of view.

CORROSION CELL – GENERATOR OF TROUBLES AND SOURCE OF SOLUTION

Understanding the principles of how electrochemical cells function is a starting point in corrosion protection. Composition of all three types of electrochemical cells, i.e. the electrolysis, galvanic and corrosion cell, is practically the same, as shown in Fig. 1. They all contain 2 electrodes connected by an ionic conductive medium (electrolyte) and an electronic conductor.

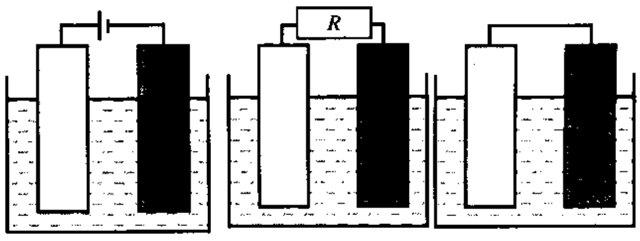

Fig. 1. Schematic of electrochemical cells variety

The electronic conductor in the case of corrosion cell is a short circuit, and this determines the nature of the processes taking part in such a cell. Thus, metal corrodes at the anode, regardless of whether it is a well-defined macro-electrode or a part of an integral metal surface finely divided into randomly spaced micro-anodes and micro-cathodes. In conjunction, a reduction process occurs at the cathode (cathodic surfaces), most frequently including conversion of dissolved oxygen or/and hydrogen ions into hydroxyl ions or/and hydrogen gas, respectively. Anode and cathode exchange both electrons and ions. The former transfer is realized directly through anode-to-cathode contact, while the ions are either generated (as, e.g., OH^--ions at the cathode or Fe^{2+}-ions at the anode) or sink at the electrode surface (as, e.g., H^+-ions at the cathode). In Fig. 2 a graphical presentation of corrosion cell operation is given.

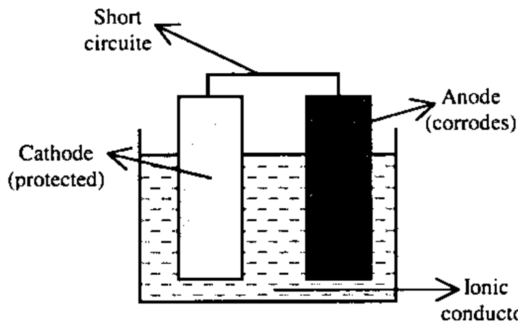

Fig. 2. Scheme of corrosion cell construction and operation. Corrosion cell is complete only when two electronic conductors (anode and cathode) are connected by short circuit and ionic conductor

Detailed knowledge of corrosion cell composition and function is not necessary only for understanding the course of corrosion reaction. It is also of great help in building the strategy how to prevent its action and numerous harmful consequences. Avoiding at least one of the listed 4 components of a typical corrosion cell is the way to stop, or at least reduce, its formation and function.

In some cases, as shown bellow, even formal (not real) avoiding is of help in reaching the protection goal.

In view of this simple principle, all corrosion protection measures (remedies) could be named as follows:

a) Electrolyte

1. Eliminate the electrolyte from corrosion cell

"Dry" corrosion cell will immediately stop its action due to lack of ionic conductor between the electrodes. The absence of liquid is also a condition for elimination of dissolved oxygen, hydrogen ions or any other potential corrosion-promoting agent (see Fig. 3a).

2. Eliminate the oxidation agent only

If the former remedy is not feasible for any reason, lowering of corrosion rate could be achieved by elimination of those components in the electrolyte that cause the corrosion reaction (see Fig. 3b). In most cases, it is enough to eliminate dissolved oxygen (by de-aeration or similar oxygen removing procedure) or the excess hydrogen ions (by neutralizing the electrolyte). As an ultimate procedure, proper inhibitor is to be applied, to stop or lower the rate of anodic, cathodic or both corrosion reactions.

3. Neutralize the action of the electrolyte

Apparent elimination of the electrolyte is achieved by applying coatings that insulate the metal surface from the bulk or thin film electrolyte (see Fig. 3c).

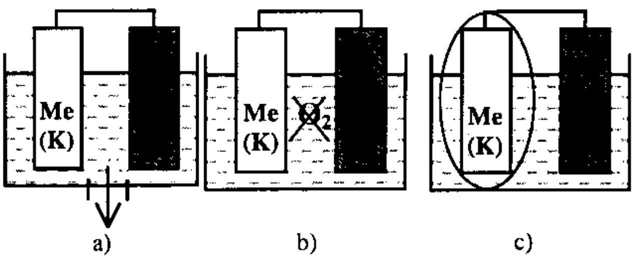

Fig. 3. Remedies in the electrolyte aimed to stop/reduce the corrosion activity: a) elimination (drainage or similar) of the electrolyte, b) removing of the oxidation agent, c) applying coatings on the metal surface

Even though absolute insulation of the metallic surface is hard or costly to achieve, this is the most frequently measure used, especially against the corrosion of metals exposed to the atmosphere. Similar is the effect produced by passivation (anodic protection) or by means of some inhibitors.

b) Cathode

1. Eliminate the cathode

Taking the cathode out of the corrosion cell (see Fig. 4a) eliminates the surface where dissolved oxygen, hydrogen ions, or other agents accept electrons generated at the anode as a result of the oxidation that take place there. Normally, with this action, one stops the advance of corrosion process. Similar effect is achieved by cutting the cathode's contact with the anode.

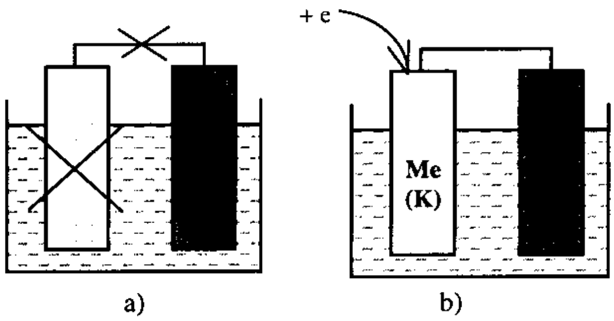

Fig. 4. Remedies at the cathode aimed to stop/reduce the corrosion cell activity: a) elimination of the cathode, b) application of cathodic protection

In case of micro-galvanic cell, where the number of cathodes is large, both of these measures are impossible. Instead, refining of the corroding metal (aimed at removing the impurities that serve as efficient micro-cathodes) or its alloying (aimed at neutralizing the impurity's cathodic activity) is an equivalent measure.

2. Neutralize the action of the cathode

If none of the cathode elimination measures is feasible, there is still another way of neutralizing the harmful effect of the cathode. It is known as cathodic protection (see Fig. 4b [6]). This is an active (permanent) protection measure of passing protective d.c. current that opposes and vanishes the effect of corrosion current flowing through the corrosion cell. In other words, this is equivalent to returning to the anode the electrons consumed by the cathode, so that oxidation of the anode stops.

Unfortunately, this effective method could be applied only in cases when a bulk electrolyte is present (as in immersed or underground structures) so that flow of protective current is feasible.

c) Anode

1. Eliminate the anode

This is only a hypothetical measure, because the anode is the corroding metal (Fig. 5). Literally it may mean to replace the metal with some other material (plastics, rubber or similar), but this is neither simple nor justified (also this is not favorable to those who make their living in metallurgy and adherent activities such as corrosion protection).

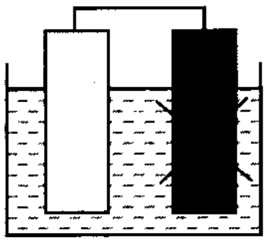

Fig. 5. Elimination of the anode as hypothetical remedy against corrosion

d) Short circuit

1. Eliminate the electronic conductor

Breaking the flow of electrons from the anode to the cathode stops the corrosion cell activity (Fig. 6).

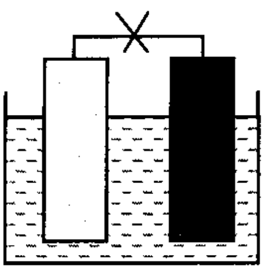

Fig. 6. Breaking the anode-to-cathode short circuit is an effective remedy (applicable only in some cases)

This measure is feasible only in macrogalvanic cells (where the anode and cathode are clearly separated) and is known as "*avoid contact of dissimilar metals*". This measure is part of a category known as *corrosion protection by design*. Other measures are, e.g., prevent water retention (ensure proper drainage), simplify the forms, etc.

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By carefully reading the above list of corrosion protection measures derived out of the corrosion cell concept, one can see that it contains all the elements that in the corrosion textbooks are usually organized in a different manner. For example, the G. Wranglen's five measures [2] named *corrosion protection*:

– change of corroding media,
– change of corroding metal,
– change of electrode potential,
– coatings and
– design

are all present in the suggested measures. The advantage of the approach presented here is that all measures have their origin in the corrosion cell concept, which is a rather new way of teaching corrosion science.

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