¿POR QUÉ NO SE PRESTA SUFICIENTE ATENCIÓN A LA CORROSIÓN?
WHY DO WE STILL NOT PAY SUFFICIENT ATTENTION TO CORROSION?

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Resumen: En este articulo, nos proponemos invitar a la reflexión sobre por qué no se presta suficiente atención a los problemas relacionados con la corrosión de los componentes o estructuras metálicas. Los casos prácticos de corrosión que podemos observar en nuestra vida cotidiana se presentan como ejemplos de las diferentes percepciones de los fenómenos observados en cuanto a fallos o diseño deficiente. Concluimos que la conciencia de la corrosión es necesaria para todos los que participan en la vida de un componente, desde la fase de especificación, pasando por la fabricación, hasta el tiempo en servicio, para lograr una solución técnica económicamente optimizada para una funcionalidad deseada. Se identifican algunos aspectos para mejorar la conciencia en la educación, en la industria y en su interacción.
Palabras clave: corrosión, mentalización, inspección visual, mantenimiento, impacto

Abstract: In this paper, we intend to invite reflection on why insufficient attention is paid to the problems associated with the corrosion of metallic components or structures. Practical corrosion cases that we may observe in our daily life are presented as examples for different perceptions of the observed phenomena in terms of failure or poor design. We conclude that all who participate in a component´s lifetime, from the specification phase over manufacturing through the time in service, in order to achieve an economically optimized technical solution for a desired functionality, require awareness of corrosion. Some aspects for improving the awareness are identified in education, in industry, and in their interaction.
Key words: corrosion, awareness, impact, visual inspection, maintenance

1. INTRODUCTION

Corrosion is a ubiquitous and costly problem for the society and, in particular, a variety of industries is involved in. Understanding and reducing the cost of corrosion remain primary interests for corrosion professionals and relevant asset owners without forgetting the additional impact as social and environmental. Therefore, the term “corrosion costs” includes all corrosion impact, particularly relevant to decision makers in the industry and government. The report of Uhlig [1] and the method of Hoar [2] have been the basis to study corrosion cost in several countries. Currently, corrosion costs for industrial countries are estimated by ca 3.5% of the gross domestic product [3-4], wherein the transportation and electronics industries generate the highest costs [4]. However, corrosion cost estimation is not easy and requires quite some efforts from all involved parts [5-7].

The fault of knowledge about corrosion phenomena, an absence of interest on it, a lack of inspection or erroneous protocol and fault of maintenance are the main reasons for corrosion being still a problem pending to get under control. There are so many signs of corroded components, structures, even with visually dramatic appearance, that could be the first alarm to act against corrosion. However, this ideal scenario is not true, although we are living in the 21th century. Therefore, the things are nor running fine [8].

The main aim of this paper is to invite the reflection of why sufficient attention is not paid to the problems entailed by corrosion of metallic components or structures, using some photos of our day-to-day practical cases as examples and for visualization.

2. PRACTICAL CASES

2.1. Roof sheet of galvanized steel

Figure 1 presents the view of a roof made from galvanized steel, observed in rural, alpine area. Although its visual appearance looks catastrophic, it is still free of leaks. *A case of corrosion failure?*

Figure 1. Roof made from galvanized steel, after years of service in rural, alpine climate.

2.2. Handrail at Sardinero beach

The city of Santander in the north of Spain is exposed to the coastal climate controlled by the Cantabric sea. Over the years, the handrails of Sardinero beach were destroyed by corrosion. In a kind of “maintenance” work, coating was applied on corroded surfaces and/or old paint without pretreatment. Within short time, the un-esthetic and safety critical situation re-appeared (Figure 2). *How can this happen?*

Figure 2. Second Sardinero beach corroded handrail. From top: General view, broken pipe detail, corrosion products underneath the coating. (View *after* maintenance work).

2.3. Supermarket trolleys

Trolleys such as the one in Figure 3, from a particular producer, developed unsighted appearance after (compared to other products) relatively short time in service, in supermarkets at various locations. *A case of poor material selection?*

Figure 3. Supermarket trolley with severe indications of corrosion (e.g. detail right), giving an untidy impression.

2.4. Kaplan turbines in a hydropower plant

Few months after taking in service, turbine runners made from nickel-aluminium bronze (NAB) developed green spots - obviously accumulations of corrosion products covering localized loss of material, see Figure 4. The fresh water of very low salinity indicates evanescent corrosiveness for NAB, not explaining this phenomenon. In addition, the galvanic coupling to the runner ring made of stainless steel (SS) is generally known to be a feasible technical solution in fresh water. *A case of poorly produced cast material?*.

Figure 4. Kaplan runner enclosed by the runner ring (left), with numerous green tubercles (middle) covering pit-like metal loss of several mm diameter (right).

3. HOW MUCH CORROSION PROTECTION DO WE NEED?

By looking into ISO 8044 [9], we learn that corrosion is defined as the reaction of a (metallic) material, which may (not will!) lead to failure. Only if corrosion phenomena impair the function of a component or a whole system, we should speak about a corrosion failure. In other words, corrosion appears acceptable as long as the function of a system is not compromised. This reflects the fact that nearly all our metallic construction materials tend to react with the natural environment and therefore are prone to corrosion – but luckily, this does not automatically imply failures.

Based on these considerations, when designing a component, we should first ask: What is the functionality of the component, what could be the consequence of a failure, and what is the desired lifetime? Not only mechanical integrity is of importance: Visual appearance is another frequently desired functionality; the kind of corrosions products may be of importance with respect to contamination of the component´s environment; the possible mode of failure (pitting/uniform corrosion, ductile/brittle fracture) may be relevant; maintainability and its related costs must be considered.

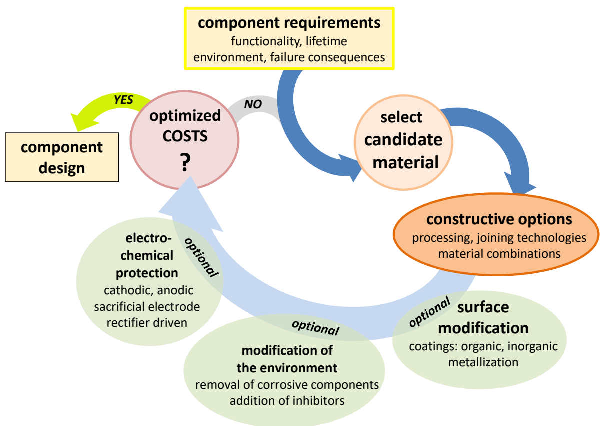

Figure 5. Flowchart of component/system design, considering all basic technical options of corrosion protection and cost optimization.

Finally, a profile of requirements must be defined and, by taking into account the environment of an application, an economically viable combination of material, its processing technology, and feasible corrosion protection method must be chosen, promising to fulfil the requirements. Figure 5 visualizes this complex process of optimization.

In this sense, the practical case #1 does not represent a failure scenario, considering tightness of the roof being its function, and its esthetic aspect being not relevant. The rusty appearance is just a corrosion phenomenon indicating the approaching end of lifetime. Lifetime was pre-determined by material selection for the exposition class of this particular climate with respect to atmospheric corrosion, and could be estimated from suitable data sources.

By looking at practical case #2 we may analyze: The original design of the handrails had two functionalities: Mechanical integrity (safety) and visual appearance (decorative). We do not know about the desired lifetime, but the designers decided on carbon steel/cast iron plus coating. This inevitably implies the need of regular maintenance intervals for extending lifetime in coastal environments to timespans relevant in public installations (typ. 50+ years). Refurbishment was decided at a stage with rather high degree of corrosion damage and only the decorative functionality was taken into account. Presumably by lack of awareness, lack of expertise in proper coating application, and by ignoring the critical aspect of structural integrity, the costs of this painting must be recorded as financial losses.

In case #3, the visual appearance of such trolleys is of great importance for the image of any supermarket chain. Thus, although the mechanical integrity is not affected at all, this case may be indeed considered a failure: The trolleys look disgusting. It is inviting to blame poor material selection the cause for failure, but galvanized steel rods with a transparent coating, as was chosen in this case, is also the technical solution of the long living competitor´s products. In fact, in this case, the coating was found much thicker, providing some extra protection against the mechanical impacts during harsh service life in a supermarket. However, after some investigation, it turned out that it is common for supermarkets to bring their trolleys to cleaning services from time to time, where an alkaline washing solution is applied at elevated temperature. The thick coating material is unfortunately susceptible to spontaneous environmental stress cracking under the washing condition. Alkaline solution gets entrapped in cracks and underneath the coating. The galvanized zinc in contact with alkaline substance corrodes by time, creating the untidy aspect (Figure 2, right). We may assume that the selection of the coating was done without awareness of the application-typical washing procedure and/or its potential effect on the selected coating. Thus, this case represents unsuitably selected corrosion protection.

By contrast, in case #4, the selected kind and combination of materials (NAB and SS) was approved by experts for this kind of application, and there exists positive experience for this technical solution. Consequently, it is obvious to question the material quality, particularly since NAB is a cast alloy of complex microstructure and casting conditions might influence its properties. However, it quickly became clear that the material was of regular quality. It required some research to find the root cause for the indications of corrosion being related to microbial activity: Specific biofilm had developed on the SS runner ring, making it virtually much more noble than the NAB and thus creating an efficient galvanic couple [10]. Such a kind of microbially influenced corrosion has neither been identified before in such an application, nor was the mechanism published at that time. Moreover, it is impossible to predict this phenomenon from chemical and microbiological water analyses. Therefore, we may conclude that the design of the turbines was basically correct, considering the state of knowledge at that time. Nevertheless, there developed a corrosion phenomenon potentially leading to failure, which was noted at an early state thanks to the operator´s awareness of corrosion. This case must be considered one of the unavoidable cases of corrosion: It is the tuition fee we have to pay sometimes, if we consciously or unconsciously create new corrosion systems, which we are unable to describe completely, and for which experience is lacking. However, we should do our best to learn from such lessons, ideally by disseminating publicly this gain in knowledge.

4. CONCLUSIONS

Basically, all our metallic materials react with the environment in their application, i.e. they corrode. This lies in the nature of the metals used, it is predetermined by thermodynamics. However, luckily, this does not necessarily imply corrosion failures. In many corrosion systems, defined by material, environment and operating conditions, the reaction results in protective or passive layers, which cause the corrosion process to slow down such that component lifetimes are, achieved which are acceptable in the particular application. Alternatively, protective measures such as coatings, inhibitors, or electrochemical protection, may be taken to reach this goal. When designing a system, the economically most effective technical solution with maximum performance is wanted and its cost must be considered unavoidable at the current state of technology.

Although this strategy sounds simple, reality of material application is far from operating at the economical optimum. This is demonstrated in cost of corrosion studies over and over again and appears ironic because our knowledge on corrosion is increasing day by day, taken the raising numbers of related publications.

Out of doubt, research must go on, not only in designing new materials, but also in developing and improving models for lifetime prediction for all kinds of applications. The latter is a challenging task in view of the complexity of the real world, and it requires efficient transfer of practical experience from real life to research institutions. However, this is just one side of the coin.

The other side of the coin is the lack of transfer of existing knowledge to practical life: Too many corrosion failure cases could be avoided by applying already existing knowledge. This is not only observed by the authors day by day in routine failure cases or just by observation in the street [11], it is also noted in studies and surveys [4].

The problem of transferring scientific knowledge to practical application is not unique to corrosion, but it plays a crucial role there. This is challenging for both, academic institutions and companies. No doubt, education could be improved since we are missing the topic of corrosion in too many technical curricula. It is not the expert level which is required, at least awareness of the phenomena and basics of the existing control technologies should be conveyed. Conversely, the management in related business units should have a minimum understanding for the issue and particularly for the consequences of ignoring it - which are economically, at the end.

Finally, please consider what we tried to exemplify by the cases presented here:

Look around you and see it, BE AWARE OF CORROSION!

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