Composite Structures

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Increasing the Security in Exploitation of Steel Structures by Correct Managing the Corrosion Phenomenon

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Summary

The sustainable development of the modern society involves an extensive knowledge of the environmental conditions - of all the factors that produce decay or, on the contrary, improve its state. An increase of the security during the service life of the steel structures is imposed by all the measures taken during the process of corrosion management.

The corrosion phenomenon is put into evidence by the irrevocable distruction of metallic elements and its particular nature determined the development of new detailed monitoring techniques and procedures that led to its better understanding by the specialists working in this particular science field.

The complexity of its manifestation, the various factors that influence the corrosion patterns make this phenomenon impossible to be described by general features. For this reason, the solutions adopted for a best corrosion protection must be the result of well organised systematic approaches and a careful planning of the corrosion management .

Keywords: sustainable development, metallic corrosion, steel structures, corrosion management

1. SUSTAINABLE DEVELOPMENT CONCEPT IN THE DOMAIN OF METALLIC CONSTRUCTIONS

The modern concept regarding the quality and performances of the constructions includes the basic criteria of sustainability, which is essential for the steel structures exploited in particular aggressive environmental conditions. This concept implies not only reaching a prior degree of technical characteristics but also maintaining them unaltered for their entire expected period of normal exploitation of the construction.

The promotion of this concept is based on extensive knowledge of the real state of the environment and also, of the factors that may cause degradation or, on the contrary, an increase of its general qualities. For this reason it is very important to study the ways of affecting this environment by the human presence, whether it is an alteration or an increase of these qualities.

The analysis of causes and consequences of the human presence integrated in environment is the principal objectives of study in the concept of sustainable development and in this respect, the links between the human society and the natural conditions must be very well understood in order to elaborate specific techniques to foresee and evaluate the impact of entropic elements at the environmental level. This major goal may be reached by developing and using new techniques of analysis and prognoses for an accurate evaluation and monitoring of the impact of the human communities on the natural global eco-systems.

2. NEGATIVE EFFECTS OF THE CORROSION OF METALS

Corrosion consists in destructive effects of an aggressive environment upon the metallic elements. Its economical consequences are negative to extreme due to the massive lost of the material that insured the initial capacities of resistance. The diminished resistance affects the security of normal exploitation of the constructions and also a dramatic reduction of their service life. Increased costs of maintenance and sometimes pollution in general and in particular, the impurities of the finite products are second order effects of the corrosion presence in the elements of construction.

We associate the corrosion phenomenon with the concept of a sustainable development in different areas of human activities and the implications of its presence act directly upon the various measures of protection, mostly all the time being the result of the compromise between many technical, economical and ecological criteria.

It is a common aspect to identify corrosion with one of the most serious threats in the economy of the modern society, increasing the costs of maintenance and development and generally being the cause of an important annual lost of material, the equivalent of hundreds of billions dollars.

Since the first significant report of Uhlig in 1949, according to which the costs of corrosion to nations is indeed great [1], numerous studies dedicated to this phenomenon were in charge of several countries including, the Unites States, the United Kingdom, Japan, Australia, Kuwait, Germany, Finland, Sweden, India and China.

The studies have ranged from formal and extensive efforts to informal and modest efforts. The common finding of these studies was that the annual corrosion costs ranged from approximately 1 to 5 percent of the Gross National Product (GNP) of each nation and further on, the conclusion of all subsequent studies has been that corrosion represents a constant charge to nations' Gross National Product.

Several studies separated the total corrosion costs into two parts:

• the portion of the total corrosion cost that could be avoided if better corrosion control practices were used;
• the situations when savings require new and advanced technology (currently unavoidable costs).

Estimates of avoidable corrosion costs varied widely with a range from 10% to 40% of the total cost. Most of the studies allocated corrosion costs to industrial sectors or to categories of corrosion control products and services. New technologies to prevent corrosion continue to be developed and cost-based corrosion management techniques are available to further lower corrosion costs. However, cost-effective methods are not always implemented.

Corrosion damage can sometimes be greatly exaggerated by the circumstances. While most of the accidents due to failed components that corrode have gone non-public for reasons of liability or simply because the evidence disappeared in the catastrophic event, others have made the headlines [2].

A decreasing order of the frequency of appearance identifies the causes of corrosion damage as an unadequate anticorrosion protection method, the unexpected exploitation conditions and the lack of an efficient control and monitoring system. Failure is also caused by a bad choose of the materials of construction, of the steel sections and their connections, these being summerized as faults of the design process. To these may be added errors of manipulation at the building site, the lack of knowledge of the risks involved by different corrosion levels, the contamination of the products and also the malfunction of the control and monitoring equipments.

The depth of the analysis into the "roots" of the failure is the key to an "accurately unearthing" all of the failure sources. Looking at machinery failures one finds that there are:

- physical roots (the physical reasons why the parts failed);
- human roots (the human errors of omission or commission that resulted in the physical roots);
- latent roots (Management System Weaknesses). The deficiencies in the management systems or the management approaches that allow the human errors to continue unchecked.

In table 1 the principal primary mechanisms of the damages from 131 analyses are presented synthetically [5]. After the study of these priorities of the failure mechanisms, the competence and responsibilities of these situations in U.S.A. were identified [3]. This data set indicates that only 8% of corrosion failures are unforeseeable; in other words 92% of the corrosion failures could be preventable. The small percentage of corrosion damage attributed to a lack of human performance by the Hoar report, the Battelle studies and many others, i. e. roughly 30-40% of total corrosion damage, would be overly optimistic.

Table 1. Primary mechanisms of failure and the causes of destruction by corrosion

Primary mechanisms of failure by corrosion		Causes of destruction by corrosion in U.S.A.	
23 Corrosion	18%	Lack of proving: new design, material or process	36%
57 Fatigue	44%	Lack of, or wrong specifications	16%
15 Wear	11%	Bad inspection	10%
17 Corrosion Fatigue	13%	Human error	12%
19 Overload	15%	Poor planning and coordination	14%
		Other	4%
		Unforeseeable	8%

Considering the corrosion types of most of the common damages, the pie chart in fig. 1 summarizes the findings of 363 corrosion failure cases investigated in a major chemical processing company [4]. The importance of pitting comes second (22%) after general corrosion and before stress corrosion cracking (SCC) which is, by the way, often initiated by pitting. Crevice corrosion comes fourth at 12%.

3. CORROSION MANAGEMENT

While corrosion will always remain a threat, there are many barriers that can be deployed to protect a system against the environment corrosion severity.

The *first barrier* is awareness and the tool to create awareness is through education and training. The *second barrier* is to do it right in the first place. Metals are naturally more stable in their non-metal states such as oxides and sulphides. Given a chance they will revert back spontaneously to the comfortable states. Designers often forget this basic law of nature. The *third barrier* is through management. Corrosion can be managed if the right decisions are based from the start on the full life cycle of a system. Buying systems and components without considerations for subsequent maintenance is flawed and can be very expensive.

Increasing the security in exploitation by correct managing the corrosion phenomenon

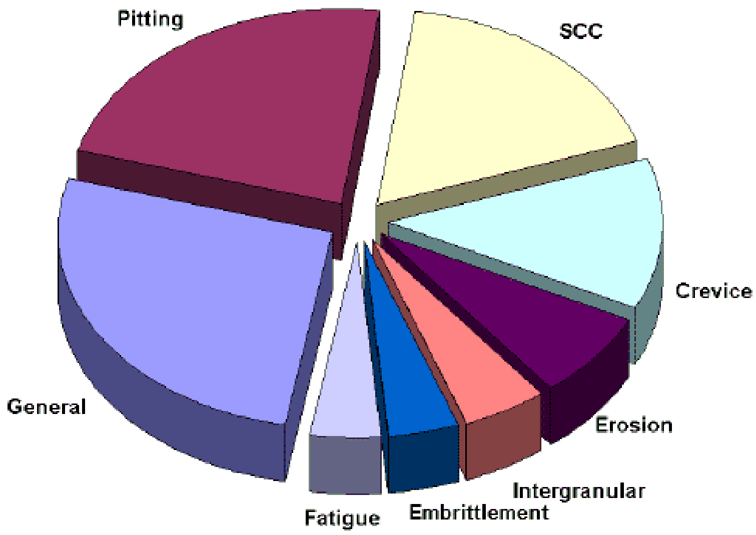

Figure 1. Types of corrosion that affects the chemical industrial field

"Corrosion management is that part of the overall management system, which is concerned with the development, implementation, review and maintenance of the corrosion policy." [2]. Corrosion management includes all activities throughout the lifetime of the structure that are performed to mitigate corrosion, to repair corrosion induced damage, and to replace the structure, which has become unusable as a result of corrosion. In general, maintenance is defined as an activity that maintains the level of service of a structure or facility.

Repair activities restore the damaged structure to its original or required service levels, but do not eliminate the causes of corrosion. Rehabilitation activities restore the damaged structure to its original or required service level and correct the deficiency that resulted in corrosion deterioration. The repair and rehabilitation activities are performed at different times throughout the lifetime of the structure. Maintenance is considered a regular activity, characterized by an annual cost. Inspections are scheduled periodic activities, and repair is performed on an as-needed basis. Repair can involve the replacement of parts, but not the replacement of the basic structure. Rehabilitation of structures such as bridges is usually done only once or twice during the lifetime of the structure, generally at a high cost.

The complexity of engineering systems is growing steadily with the introduction of advanced materials and modern protective methods. This increasing technical complexity is paralleled by an increasing awareness of the risks, hazards and liabilities related to the operation of engineering systems. The increasing cost to replace equipment is forcing people and organizations to extend the useful life of their systems.

Identification of hazards, assessment of risks and agreement on planned activities is a fundamental requirement of the management process.

Even at the most basic level, there are multiple interactions between defects (departure of a characteristic of a system from requirements), faults (inability of s system to perform a required function) and the failure of a system (termination of the ability of a system to perform a required function).

The prediction of damage caused by environmental factors remains a serious challenge during the handling of real life problems or the training of adequate personnel. Mechanical forces, which have normally little effect on the general corrosion of metals, can act in synergy with operational environments to cause the most sudden failures by localized mechanisms.

To determine the probability of a failure, two fundamental issues must be considered:

- what are the specific forms of corrosion and their rates,
- what is the possible effectiveness of inspection.

The input of corrosion experts is required to identify the relevant forms of corrosion in a given situation and to determine the key variables affecting the propagation rate. It is also important to realize that full consensus and supporting data on the variables involved is highly unlikely in real-life complex systems and that simplification will often be necessary.

The evolution of the corrosion process characterised by the corrosion rate marks the extense of the period of service in normal conditions of the metallic element as part of the construction. On the other hand, the measurements of the corrosion effects and the necessary remedies of the corrosion proces inits full development are actions that imply important costs. For this reason oly, the monitoring of the corrosion phenomenon is important, the specific techniques having as a result:

- a precocious detection of the development of the conditions of a further damaging process;
- the indication of the corelation between the modification of the parameters of the process and the effect upon the corrosion status of the system;
- diagnosis of a particular corrosion situation, the identification of its causes and the parameters that determine the evolution of the corrosion (the corrosion rate);
- the evaluation of the efficacy of the program of control/monitoring and preventing of the corrosion;
- providing of the necessary information of the stages of evolution of the corrosion for a better management of the phenomenon.

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The last mentioned elements are the proof that corrosion is indeed a complex phenomenon and its multiple various factors sometimes lead to specific unavoidable manifestations. The solutions must be the result of a systematic approach.

The current study showed that technological changes have provided many new ways to prevent corrosion, and the improved use of available corrosion management techniques. However, better corrosion management can be achieved using preventive strategies in non-technical and technical areas. These preventive strategies include:

- increase awareness of large corrosion costs and potential savings,
- change the misconception that nothing can be done about corrosion,
- change policies, regulations, standards, and management practices to increase corrosion saving through sound corrosion management,
- improve education and training of staff in recognition of corrosion control,
- advance design practices for better corrosion management,
- advance life prediction and performance assessment methods.
- advance corrosion technology through research, development, and implementation.

There are many different ways the above issues can be achieved. This will be dependent on the size of the organization and the extent or otherwise that various duties and responsibilities are contracted or sub-contracted out to third party organizations. In fig. 2 a corrosion management flow chart is presented.

Planning and implementation of the corrosion management must eliminate all the damages or, at least must reduce at minimum their risks.

Planning includes: the identification of corrosion threats and consequences; ranking of systems and components in order of corrosion risk; selection of appropriate mitigation and management activities; scheduling of tasks.

Implementation ensures that actions identified in the planning stage are carried out as required and includes: translation of the plan into a detailed set of work packs; identification of the locations for monitoring and inspection activities; procedures for execution monitoring and inspection activities; development of acceptance criteria; development of performance measures; definition of the reporting routes; data gathering and management; analysis of data; reporting; corrective action or application of corrosion control measures.

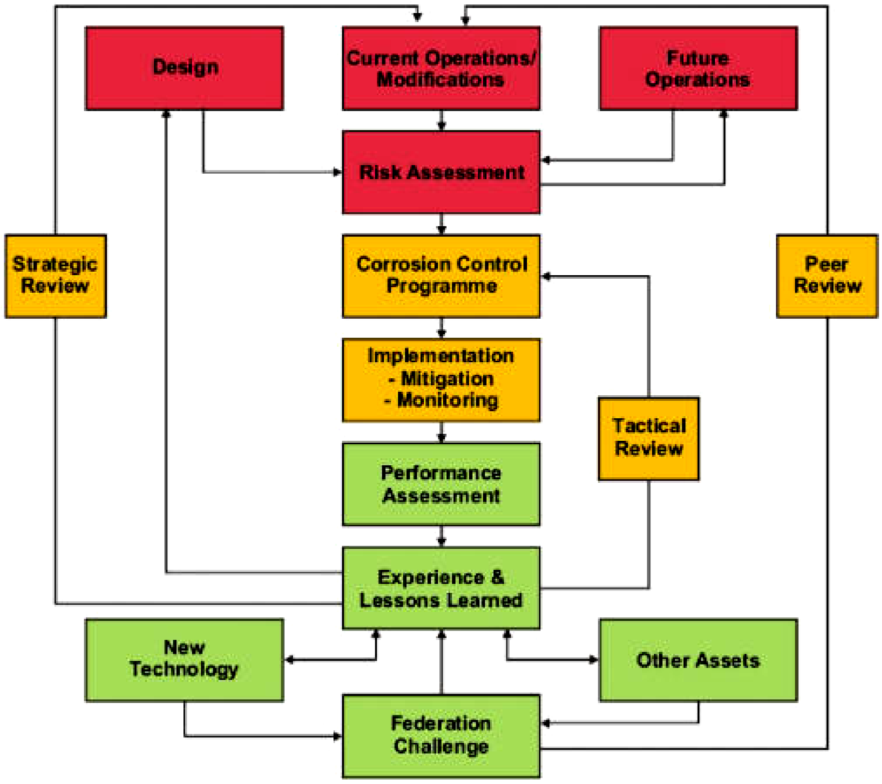

Figure 2. Example of corrosion management system [2], [5]

All organizations should have in place policies and strategies that deal with hazards and risks associated with safety, health and environmental concerns. Thus, although many companies may not have a stated corrosion policy, all accept the inherent concept of good corrosion management practice is implied and is incorporated into their planning process.

Development of strategies for corrosion management involves:

i) Overall management of corrosion risks: ensuring responsibility for corrosion management resides with a named individual whose authority should be equal to his responsibility; ensuring roles and responsibilities match the required competency; integrating corrosion management with safety and asset management and to inspection, maintenance and operations strategies; ensuring that risk assessment procedures remain live and are updated on a regular basis; providing an auditable trail for corrosion risk/criticality assessments; ensuring feed back from field experience into new designs and particularly that adequate corrosion input occurs at the concept stage.

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ii) Effective deployment of human resources: ensuring that adequate resources are available; ensuring technical and managerial competence, particularly where multi-skill manning is involved corrosion issues are delegated and become the responsibility of a non-specialist; involving all appropriate team members in sharing of information; evolving a proactive culture.

iii) Development of appropriate organizational structures: ensuring key information gets to the right people; using appropriate information control systems.

iv) Systems to meet changing situations: ensuring process fluids are monitored to identify changes of the corrosion process; updating and auditing all systems when implementing organizational changes; providing benchmarks and audits from which to develop future strategies; developing opportunity based inspection procedures.

The effectiveness of any policy depends on the leadership, commitment and involvement of managers and senior staff.

For organizing corrosion management the four “Cs” of a positive culture are: control, communication, competence, co-operation. Consideration of these four Cs is vital, particularly for management of complex multi-disciplinary areas, like corrosion management, which may well involve engineers that are not specialized in this respect.

4. CONCLUSIONS

In the present, corrosion phenomenon is better understood but in the same time the destruction of metals and the lost of material are a common presence in every domain. That is why new advanced techniques and methods of the control of this phenomenon are a continuous necessity.

The increasing quality of the materials used in the metallic constructions (mostly steel and aluminium), the new and notable technologies and products with higher resistance in aggressive environmental conditions challenges day by day the continuous evolution of the complex parameters of this aggressiveness.

A competition is born between corrosion and its remedies. As a direct implication, the solutions of protection tend to become more specific, directly used and easier to apply. Choosing certain specific systems of protection is the decision of personnel with high training and experience in this field.

Planning and management of the corrosion status must insure the elimination of the failure of materials for the life time of the construction and at least, must reduce to minimum the risks involved for the human occupancy and the costs of the accidental situations.

An efficient management of the corrosion may be concieved by using strategies of adequate preventing methods and this is the responsability of the engineer specialised in corrosion.

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