ITTC

Innovation and Technology Transfer Centre
University of Miskolc

XXIII. microCAD International Scientific Conference 19-20 March 2009

O szekció: Anyagáramlási rendszerek. Logisztikai informatika

Section O: Material Flow Systems. Logistical Information Technology

NKTH

Nemzeti Kutatási és Technológiai Hivatal

A projekt a Nemzeti Kutatási és Technológiai Hivatal támogatásával valósult meg.

Társrendező: *MTA Közlekedéstudományi Bizottság Logisztikai Albizottság*

Kiadja *a Miskolci Egyetem Innovációs és Technológia Transzfer Centruma*
Kiadásért felelős: *Dr. Dobróka Mihály rektorhelyettes*
Szerkesztők: *Dr. Lehoczky László osztályvezető*
Nyomda: *ME Sokszorosító Üzeme*
Üzemvezető: *Kovács Tiborné*
Nyomdaszám: *ME.Tu-115/2009.*
ISBN 978-963-661-866-7 ö
ISBN 978-963-661-880-3

SURFACE PROTECTION AND COATING AT ENGINEERING STRUCTURES

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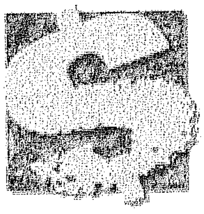
1. INTRODUCTION

In the '80s the world's corrosion wastage was nearly 33% at steel structures. This quantity is more than 4% of the Hungarian national income per year. These amounts show the fact, that the surface protection is a very important technology in the steel structure design. However we may not fully cease the harms, but suiting methods' wide cycle stands behest corrosion wastages' reduction. Only one method is not satisfying in every situation. The surface protecting is need a complex designing, technological and measuring processing. We may step up effectively only with organization, economic and technical analyzing the active protection.

Corrosion means the breaking down of essential properties in a material due to chemical reactions with its surroundings. In the most common use of the word, this means a loss of electrons of metals reacting with water and oxygen. Widespread data collecting and data processing fundament are useful against the corrosion problems. Surface coatings, especially the more known used paint coatings are very important in all branches of science and technology. The most public corrosion case is the atmospheric corrosion. The atmospheric relation's description is already solvable.

There was a US research on corrosion costs and preventive strategies [1]. The industry sectors for corrosion cost analyses represented approximately 27 percent of the U.S. economy gross domestic product (GDP), and were divided among five sector categories: infrastructure, utilities, transportation, production and manufacturing, and government. The total cost of corrosion was estimated by determining the percentage of the GDP of those industry sectors for which direct corrosion costs were estimated and extrapolating these numbers to the total U.S. GDP. The direct cost used in this analysis was defined as the cost incurred by owners or operators of the structures, manufacturers of products, and suppliers of services (see Table 1).

The following elements were included in these costs:



- Cost of additional or more expensive material used to prevent corrosion damage.
- Cost of labour attributed to corrosion management activities.
- Cost of the equipment required because of corrosion-related activities.
- Loss of revenue due to disruption in supply of product.
- Cost of loss of reliability.
- Cost of lost capital due to corrosion deterioration.

Table1. Summary of estimated direct cost of corrosion for industry sectors analyzed

CATEGORY	ESTIMATED	DIRECT
	USD x billion	percent*
Infrastructure (16.4% of total)		
Highway Bridges	8.3	37
Gas and Liquid Transmission Pipelines	7.0	27
Waterways and Ports	0.3	1
Hazardous Materials Storage	7.0	31
Airports	**	**
Railroads	**	**
Utilities (34.7% of total)		
Gas Distribution	5.0	10
Drinking Water and Sewer Systems	36.0	75
Electrical Utilities	6.9	14
Telecommunications	**	**
Transportation (21.5% of total)		
Motor Vehicles	2.7	9
Ships		
Aircraft	2.2	7
Railroad Cars	0.5	2
Hazardous Materials Transport	0.9	3
Production and Manufacturing (12.8% of total)		
Oil and Gas Exploration and Production	1.4	8
Mining	0.1	1
Petroleum Refining	3.7	21
Chemical, Petrochemical, and Pharmaceutical	1.7	10
Pulp and Paper	6.0	34
Agricultural	1.1	6
Food Processing	2.1	12
Electronics	**	**
Home Appliances	1.5	9
Government (14.6% of total)		
Defense	20.0	99.5
Nuclear Waste Storage	0.1	0.5
TOTAL	**$ 137.9**	

*Individual values do not add up to 100% because of rounding.
**Corrosion costs not determined.

Corrosion Control Methods and Services

The corrosion control methods that were considered include protective coatings, corrosion-resistant alloys, corrosion inhibitors, polymers, anodes, cathodic protection, and corrosion control and monitoring equipment. Other contributors to the total annual direct cost that were reviewed in this report are contract services (i.e., non-owner/operator services), corrosion research and development, and education and training.

Protective Coatings – Both organic and metallic coatings are used to provide protection against corrosion of metallic substrates. These metallic substrates, mostly carbon steel, will corrode in the absence of the coating, resulting in the reduction of the service life of the steel part or component.
The most widely used metallic coating for corrosion protection is galvanizing, which involves the application of metallic zinc to carbon steel for corrosion control purposes. Hot-dip galvanizing is the most common process, and as the name implies, it consists of dipping the steel member into a bath of molten zinc.

Corrosion-Resistant Alloys – Corrosion-resistant alloys are used where corrosive conditions prohibit the use of carbon steels and protective coatings do not provide sufficient protection or are economically not feasible. Examples of these alloys include stainless steels, nickel-base alloys, and titanium alloys. Where environments become particularly severe, nickel-base and titanium alloys are used. Nickel-base alloys are used extensively in the oil production and refinery and chemical process industries, where conditions are aggressive. Furthermore, there is increased use of these alloys in other industries, where high temperatures and/or severe corrosive conditions exist.
The primary use of titanium alloys is in the aerospace and military industry, where the high strength-to-weight ratio and resistance to high temperatures are properties of interest. However, titanium and its alloys are also corrosion-resistant to many environments and have, therefore, found application in oil production and refinery, chemical process, and pulp and paper industries.

Corrosion Inhibitors – A corrosion inhibitor may be defined, in general terms, as a substance that when added in a small concentration to an environment effectively reduces the corrosion rate of a metal exposed to that environment. Inhibition is used internally with carbon steel pipes and vessels as an economic corrosion control alternative to stainless steels and alloys, coatings, or non-metallic composites. A particular advantage of corrosion inhibition is that it often can be implemented or changed *in situ* without disrupting a process. The major industries using corrosion inhibitors are oil and gas exploration and production, petroleum refining, chemical manufacturing, heavy manufacturing, water treatment, and the product additive industries.

Engineering Plastics and Polymers –It is difficult to estimate the fraction of plastics used for corrosion control because, in many cases, plastics and composites are used for a combination of reasons, including corrosion control, light weight, economics, strength-to-weight ratio, and other unique properties. While corrosion control is a major market for many polymers, certain polymers are used mostly, if not exclusively, for corrosion control purposes. The significant markets for corrosion control by polymers include composites (primarily glassreinforced thermosetting resins), polyvinyl chloride (PVC) pipe, polyethylene pipe, and fluoropolymers.

Cathodic and Anodic Protection – The cost of cathodic and anodic protection of metallic structures subject to corrosion can be divided into the cost of materials and the cost of installation and operation. Major markets for sacrificial anodes are the water heater market and the underground storage tank market. The cost of installation of the various cathodic protection components for underground structures varies significantly, depending on the location and the specific details of the construction.

Corrosion Control Services – In the context of this report, services are defined as companies, organizations, and individuals that provide contract services for corrosion control purposes, while excluding corrosion-related activities that owners/operators may do in-house.

Research and Development – Over the past few decades, less funding has been made available for corrosion-related research and development, which is significant in light of the costs of maintaining aging infrastructure. In fact, several government and corporate research laboratories have significantly reduced their corrosion research staff or have even closed down their research facilities. Moreover, less research and development funding has been available from either government or private sources.

Education and Training – Corrosion-related education and training in the United States includes degree programs, certification programs, company in-house training, and general education and training. A few national universities offer courses in corrosion and corrosion control as part of their engineering curriculum. Professional organizations offer courses and certification programs that range from basic corrosion to coating inspector to cathodic protection specialist.

The coating technologies have another big challenge, namely the environmental hygiene. Nowadays we can use multi-component coating without active solvents [2].

2. CORROSION DAMAGES

2.1 Immediate damages:

- Corrosion protection's cost and replacement's costs of corrosion caused fail devices.
- Resistant alloy's utilization cost.
- Block coat's application cost.
- Cathode protection's cost.

2.2 Indirect damages:

- Periodical production phase loss.
- Puncture-occurred material damage.
  - Water service drop-out
  - Electric energy service drop-out
  - News - transmitting and transportation's brake.

- Products' contamination.
- The life- and accident prevention-safety factor's decline.

3. CATHODE-REDUCTION PROCESSION

$$2H^{+}+2e\rightarrow H_2 \tag{1}$$

$$O_2+2H_2O+4e\rightarrow 4OH^{-} \tag{2}$$

$$MeO+2H^{+}+2e\rightarrow Me+H_2O \tag{3}$$

$$Me_2O_3+6H^{+}+2e\rightarrow 2Me^{2+}+3H_2O \tag{4}$$

$$Me_2O_3+6H^{+}+2e\rightarrow 2Me^{2+}+3H_2O \tag{5}$$

We deem the iron corrosion as a metallic conditioned iron transformation to hydrous, mainly from $\gamma-Fe_2O_3\cdot H_2O$ to iron oxide (6.).

$$4Fe+3O_2+2H_2O\rightarrow 2Fe_2O_3\cdot H_2O \tag{6}$$

The condition of this process's occurrence is that the oxygen and the water is presence in the same time. We can break up this process into two parts, namely the electron producing /anode/ and the electron consuming/cathode/processes (Eqs.7,8).

$$4Fe\rightarrow 4Fe^{2+}+8e \tag{7}$$

$$2O_2+4H_2O+8e\rightarrow 8OH^{-} \tag{8}$$

$$4Fe+2O_2+4H_2O\rightarrow 4Fe/OH/_2 \tag{9}$$

The reaction will continue as below, if air's presence:

$$4Fe/OH/_2+O_2\rightarrow 2FEO_3\cdot H_2O+2H_2O \tag{10}$$

4. SURFACE PREPARATION

To get a long lifetime and durable coating, first we have to prepare the surface of the structure depending on the type of corrosion (see Fig. 1). There are a wide range of preparation methods in the coating technology. Surface preparation means, that we have to clean the surface and make a corresponding roughness. We can break up the preparation methods into two parts. The first one is the derusting, and the other one is the degreasing. The derusting method is for the removing of the deposit oxide layer, while the second one is for the solution of the attached contaminations.

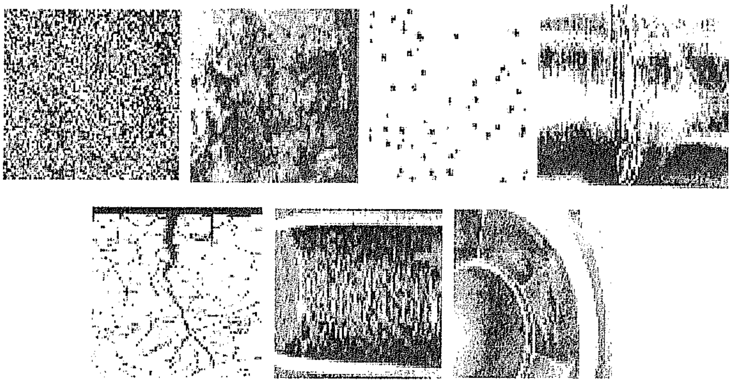


Figure 1. The basic types of corrosion; uniform-, blotched-, hole-, slot-, grain-boundary-, strain-, blast-, and cavitations' corrosion

We have to know the surface property, and the properties of the attached contaminations as; size, cragginess and wall thickness. Nowadays the most effective process is the abrasive blasting process. Abrasive blasting uses mechanical energy to hurl particles at high speeds against metallic and non-metallic surfaces, removing paints and other organic coatings. We can chose dry and wet blasting. The blaster can use powder metals, like; chippings cast iron, steel pellet and chopped steel wire, and also able to use non-metallic materials, like; glass melting sand, electro-corundum, carbon silicide or chopped glass. The diameter of the glass melting sand is form 0.7...2.0 mm, it is a clean, dry, sand-, humus-, argil- and salt free. We can design the structure's roughness with the diameter (d) and the characteristic data (K) of the usable materials (Eq. 11).

$$R_a = \frac{d \cdot 10^{-3}}{K} \tag{11}$$

Safety-technical ordinance is (for those persons whose working with the abrasive blaster) to wear a special helmet, and work in closed system, because the risk of the silicosis is high.

5. ENVIROMENTAL EFFECTS IN THE COATING TECHNOLOGY

It is more difficult to achieve a good surface finished with water or powder-based paint systems than traditional solvent-borne systems. Smaller batch sizes are significantly more expensive in terms of lost paint, solvent and colour changeover lead-time. Water-borne systems require longer colour change over lead-time than solvent and use more energy in the ovens due to the slower rate of evaporation. Paint is the biggest environmental problem that car factories face. Dealing with this takes up a major proportion of environmental expenditure. Fixed capital costs are high for emissions and waste treatment equipment. Equally, operating costs are substantial due to high energy and material use as well as material waste treatment and disposal. All this adds up to major difficulties in balancing costs in the paint plant while meeting regulatory and production expectations. The three key areas of environmental concern are as follows [3]:

- Air emissions
- Waste
- Energy

The environmental consequences of more flexible and lean production are bound to increase when shortened lead-times and smaller batch sizes are required. The metallurgical coating material is selected according to the coating-class, see on Table 2.

Table 2. Coating-classes according to material contents

Metallurgical coating material with high dry content	Classical metallurgical coating material	Metallurgical coating material with water duration
Epoxy coatings	Esterol primer coating	Primer coatings
Epoxy mastics	Esterol cover coatings	Cover coating
Ethylene-oxide esters	Epoxy primer coating	
	Epoxy topcoats	
	Polyurethane coatings	
	Primers with high zinc-contain	

We are able to reduce the amount of those acid materials, which are coming into the air during painting, if we use solvent free paints. Te solvent-exhalation is one of the most important part of the environmental pollution in the coating technologies. The solvent free painting is more economical than normal paintings, because we can save money on solvents, and the water duration is more wastless.

ACKNOWLEDGEMENT

The support of Ostorházi Coating Technology Ltd. is gratefully acknowledged. The research was also supported by the Hungarian Scientific Research Fund within the project OTKA T 75678, which is also acknowledged.

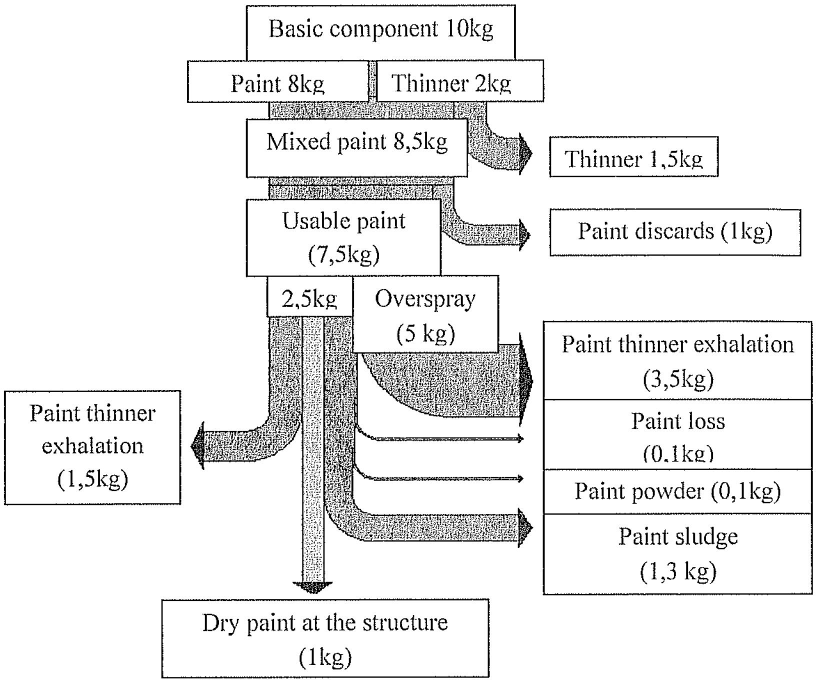


Figure 2. Thinner-used painting's economical efficiency

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