Anticorrosive efficiency of preservants for farming machinery

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ABSTRACT: Selected anticorrosion preserving agents were subjected to a comparison on the basis of tests made under operating conditions. Resistance of materials to corrosion markedly varies with operating conditions and impact of outer environment with the most important factors influencing the corrosion rate being SO_2 content, temperature and humidity. Relative protective efficiency of preserving agents was assessed on the basis of weight losses of protected and unprotected samples. It was found out that the material's resistance to corrosion is significantly depending on warehousing conditions (SO_2, temperature, humidity, etc.) and on the quality of the applied preservant. Depending on various environments, the values of relative protective efficiency of water-soluble preservant and preserving agent based on vegetable oils were ranging from 38–87% and 47–75%, respectively.

Keywords: preserving agents; resistance to corrosion; relative protective efficiency; corrosion test

All construction materials are exposed to the surrounding corrosive environment. Corrosive effects are more or less intensive and may impair service properties of materials (impaired aesthetics and heat passage, lower values of strength and plasticity, worse fracture characteristics) to such an extent that the plant or the component will loose its function. Also, an impact on the environment in which the process of corrosion takes place is not negligible (contamination of water, soil and food with ions of metals or with solid products of corrosion).

Losses due to corrosion reach up to 4–5% GNP in countries with advanced industries; this indicates that the corrosion of metals in the Czech Republic is responsible for an annual loss of nearly 10^{12} CZK (Bystrianský, Novák 2000). Estimates from some countries such as Poland speak of even higher losses due to corrosion.

The structure of corrosion losses is varied. Degradation of metals due to corrosion can result in various technical problems with both economic and environmental consequences:

- Plant shut-down and hence loss in production and related repair costs;
- Environment pollution such as leakage of dangerous or toxic substances;
- Loss of plant efficiency;
- Necessity to oversize some plants, i.e. to calculate with the corrosion impacts.

Corrosion rate

The rate of uniform corrosion, i.e. corrosion occurring on the entire metal surface at a comparable rate, is most frequently expressed in units of material thickness loss per unit time (e.g. in mm per year as mm/a) and can acquire values ranging over several orders according to the type of corrosive system (combination of metal × environment). The rate of iron (i.e. plain carbon steel – mere alloy of iron and carbon) dissolving in sulphuric acid is 50–100 mm per year; however, the corrosion rate of the same material under atmospheric conditions is ranging between 1 and 50 µm per year.

Corrosion in farming environment

Farming operations are a specific field from the viewpoint of corrosion and its control. Corrosion aggressiveness of these operations reaches high and sometimes even the highest degrees and this is why qualitative and resistant surface protection must be used.

Operations with the highest degree of corrosion aggressiveness

- Environment of industrial fertilizers and agrochemicals is one of the most aggressive environments where chemical substances come into direct contact with metallic surfaces and the corrosion is further supported by humidity. Service life of components which are in direct contact with fertilizers is about 2–3 years. Service life of plants and machines is 4 to 5 years (Jára, Havrland 1983). Environment corrosion activity 5 to ČSN ISO 12 944-5.
- Environment of animal production can be classified as the environment with corrosion activity 4 to 5 (ČSN ISO 12 944-5 Nátěrové hmoty – Protikorozní ochrana ocelových konstrukcí ochrannými nátěrový-

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Published results are a part of solution of Research plan of the Ministry of Education, Youth and Sports No. MSM 432100001.

- mi systémy – Část 5: Ochranné systémy) due to the character and intensity of animal production impacts on machines and construction segments. It is a very specific environment in which the major corrosive agents are ammonia and humidity and in which the corrosion rate of carbon steel amounts to 25–50 µm per year (JÁRA, HAVRLAND 1983).
- Environment of silages belongs in the group of environments with corrosion aggressiveness 4–5. It is a specific anaerobic environment with hydrogen depolarization, in which the major corrosive agents are organic acids.
- Environment of soils is affected by the character of soils (loamy, sandy, etc.) and the major agents are chemical substances, moisture and air contained in the soils. This environment exhibits corrosion aggressiveness 4.

Rather than expressing a short time of protection, the term of temporary corrosion control indicates that the protection is meant to end after the requested period of time and that the preservants can be removed from surfaces of products, plants or machines in an easier way than organic or metallic coats with no damage to permanent anticorrosion treatment. The means of temporary corrosion control are mainly preserving agents such as conservation oils, waxes, vaselines, emulsions, removable varnishes and coating materials, etc. and agents for packaging atmosphere treatment such as dessicants, evaporating inhibitors, etc.

Temporary corrosion control can be ensured by two ways:

- by modifying the conditions of product storage, i.e. by reducing atmosphere components with aggressive corrosion effects;
- by preventing or reducing the access of environment components with aggressive corrosion effects onto the surface of products, machines or plants, i.e. by using preservants which form a coat on the surface.

METHODOLOGY

Tests of protective efficiency of preserving agents are carried out in order to obtain data on the protective efficiency of these means of protection in atmospheric or operating conditions and in order to find out whether a certain preservant is fitted for a given environment.

Tests of some preserving agents were made in four environments: in atmospheric conditions, under a shelter to ČSN EN ISO 8565 (Kovy a slitiny. Atmosférické korozní zkoušky. Základní požadavky na staniční zkoušky, 1996), and the two remaining sites represented two operating environments – one as an unheated store and one as a store with central heating.

Environments chosen for exposition of segments:

- *Environment 1* – outdoor atmosphere;
- *Environment 2* – under shelter;
- *Environment 3* – heated room;
- *Environment 4* – unheated room.

This experiment was made with two oil-based preservants which were assessed after 1 year of exposition.

Preservants selected were Inkor Bio and Konkor 437.

Characteristics

1. Inkor Bio is a conservation oil with no content of crude oil substances, which makes use of stable properties of vegetable oils. It is well suited for temporary protection of ferrous materials against atmospheric corrosion and the expected time of corrosion control is 10 months. Inkor Bio contains a special, highly stable vegetable carrier with anticorrosive additives and inhibitors based on basic compounds. It does not include halogenides, PCB, PCT substances or phosphorus.

Use:

- large-scale conservation of fittings, bonding material, workpieces of cast iron and cast steel, temperated cast iron and products made of all steel grades;
- conservation of machines in combination with biologically degradable lubricants and cooling agents.

Producer: Triga, spol. s r.o., V Předním Hloubětíně 2/362, 190 00 Prague 9.

2. Konkor 437 is a water-soluble preservant which does not contain crude oil hydrocarbons and is well biologically degradable. The Konkor 437 preserving solution is designed for the inter-operation corrosion control up to 6 months.

Use:

- temporary, inter-operation protection of ferrous and non-ferrous metals from atmospheric corrosion at all places where crude-oil based preservants cannot be used for environmental or safety reasons.

Producer: Paramo, a.s., Přerovská 560, 530 06 Pardubice.

Experimental samples were flat plates 160 × 65 × 0.5 mm made of steel 11 321 (ČSN 41 1321, Ocel 11 321, DIN St.2, ASTM 1008, ISO Cr 01).

The samples were designated, degreased and weighed prior to coating. There were at least 3 samples chosen for each agent and site.

The samples were designated with numbers so that the markings which were made on sample surfaces that were not subjected to any visual assessment and were of no functional importance could remain legible for the entire time of exposition.

The preserving agents were applied by submerging the samples suspended on a hanger into the particular preservant at a laboratory temperature (20 ± 2°C) for a time of one minute. Agents with higher viscosities were applied by means of spatula. The 3 control samples were measured for the layer thickness (t) of applied preserving agent as expressed in g/m^2

$$t = (m_K - m)/S \qquad (\mathrm{g/m^2}) \qquad (1)$$

Table 1. Sample weight losses and relative protective efficiency of preserving agents

Sample	Environment	m_0 (g)	m_1 (g)	m_2 (g)	m_3 (g)	m_4 (g)	m_{xn} (g)	U_r
Unprotected metal sheet	1	172.217	170.159	165.863	165.029	164.952	7.2160	–
	2	168.984	168.498	166.932	166.787	166.653	2.2820	–
	3	169.969	169.725	169.634	169.627	–	0.2934	–
	4	171.690	171.436	171.402	171.388	–	0.3344	–
Preservant 1	1	173.309	171.817	169.485	169.469	0	3.8076	47.237
	2	168.644	168.461	168.047	168.034	0	0.5776	74.693
	3	172.788	–	–	–	–		100
	4	170.292	–	–	–	–		100
Preservant 2	1	171.351	170.444	166.959	166.940	0.000	4.4110	38.875
	2	168.998	168.724	168.699	168.679	0	0.2866	87.443
	3	170.568	–	–	–	–		100
	4	169.122	–	–	–	–		100

Note: m_0 – weight of the three samples prior to conservation
m_1 – weight of the three samples after 1 year of exposition and deconservation
m_2–m_n – weight of the three samples after $n - 1$ pickles
m_{xn} – weight loss due to corrosion

where: m_K – weight of the three samples after the application of the preserving agent (g),
m – weight of the three samples deconserved (g),
S – area of the three samples (m^2).

The test was launched in the autumn and lasted 12 months. The samples were regularly assessed after 1, 3, 6 and 12 months. After 1, 3, 6 months the samples were assessed only visually as the measurement in question was of assorting character whose purpose was to classify the protective agents by their protection efficiency. A greater amount of samples could be used at further measurements in samples with identical relative protection efficiency and to check on their weight loss even after 1, 3 and 6 months.Visual assessments were

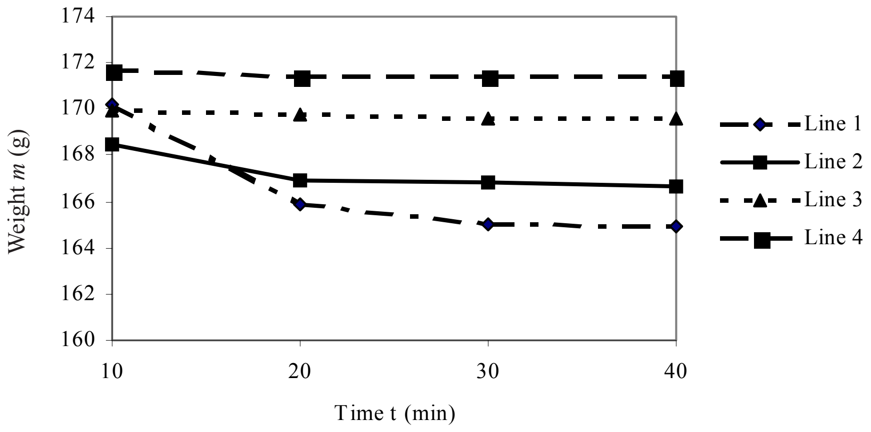

Fig. 1. Dependence of metal weight loss in unprotected samples
Line 1 – Samples exposed in the open
Line 2 – Samples exposed under shelter
Line 3 – Samples exposed in unheated store
Line 4 – Samples exposed in store with central heating

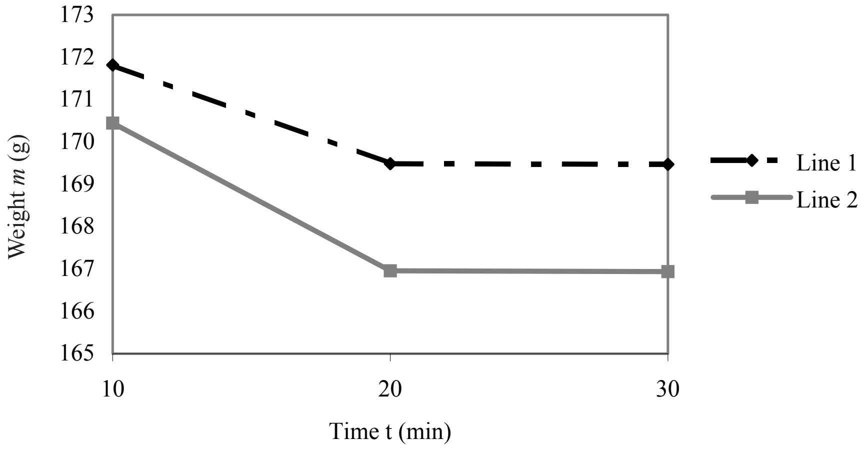

Fig. 2. Dependence of metal weight loss in conserved samples placed in the open on pickling time
Line 1 – Preservant 1 exposed in the open
Line 2 – Preservant 2 exposed in the open

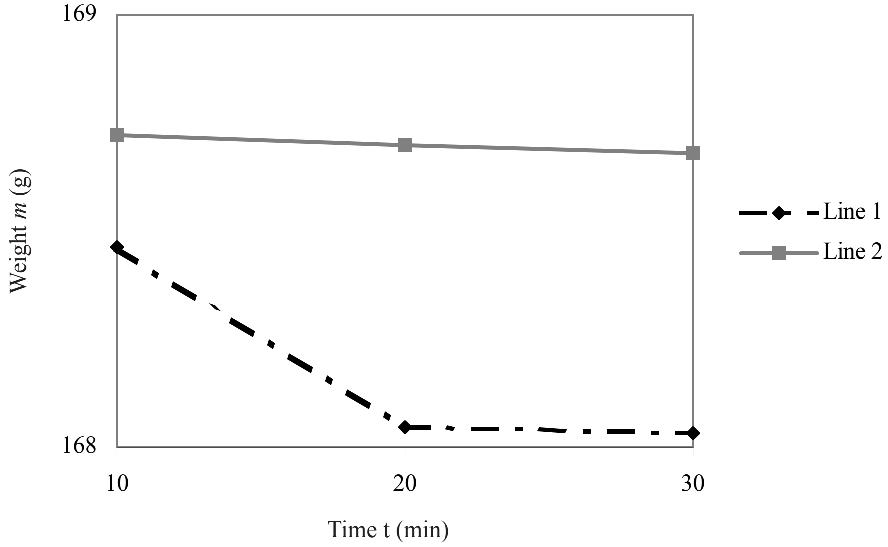

Fig. 3. Dependence of metal weight loss in conserved samples placed under shelter
Line 1 – Preservant 1 exposed under shelter
Line 2 – Preservant 2 exposed under shelter

made after 1, 3 and 6 months with a visual assessment and weight loss measurement being made after 12 months.

The weight losses were determined in accordance with ČSN ISO 8407 (ČSN 03 8102: Odstraňování korozních zplodin ze vzorků podrobených korozním zkouškám, 1994). The samples were deconserved, mechanically cleaned in order to remove low-adhesive voluminous products of corrosion. Since it was impossible to remove all products of corrosion mechanically, a chemical procedure had to be adopted, too. The chemical cleaning was made with 500 ml hydrochloric acid (HCl, $\rho = 1.19$ g/ml), 3.5 g hexamethylentetramine, and the solution was completed with distilled water to total 1,000 ml. The samples were repeatedly pickled at intervals of 10 minutes until all corrosion products were removed. After each pickling, the samples were weighed and their weight was recorded (Table 1, Figs. 1–3).

Relative preservant protective efficiency (U_r) was determined to ČSN ISO 8407 on the basis of weight losses:

$$U_r = [(\Delta m_0 - \Delta m_{1-k}) / \Delta m_0] \,.\, 100 \qquad (\%) \qquad (2)$$

where: Δm_0 – weight loss due to the corrosion of unprotected sample (g),
Δm_{1-k} – weight loss due to corrosion of preservant-protected sample (g).

RESULTS AND DISCUSSION

Determination of relative protective efficiency U_r

It follows from Figs. 1–3 that the greatest weight losses were measured in the outdoor atmosphere during a direct contact of the material with the corrosion-supporting substances and were lower in samples exposed under the shelter. The samples were cleansed (both mechanically and chemically) until all corrosion on them was removed. Results of Figs. 2 and 3 indicate that after the use of two cleansing cycles all corrosion was successfully removed and the protective agents exhibited similar weight losses with their relative protection efficiency also being nearly the same (see Table 1).

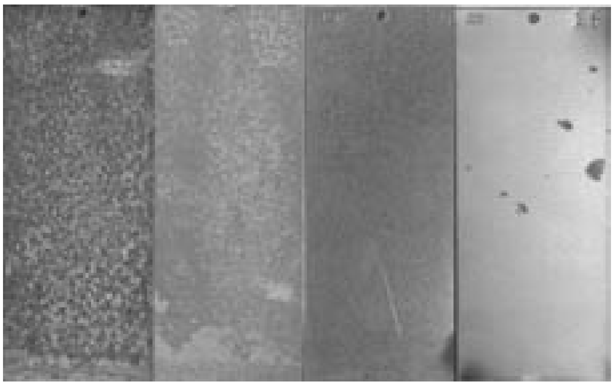

Fig. 4. Comparison of protective efficiency of preserving agents by the used environment – *Preservant 1*
(VA – outdoor atmosphere – 100% corroded area, PP – under shelter – 86% corroded area, VM – heated room – no corrosion, NM – unheated room – no corrosion)

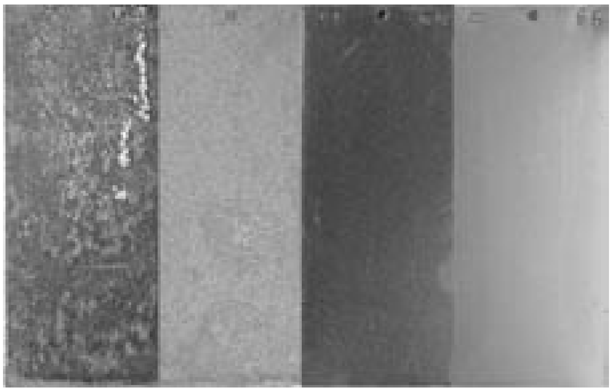

Fig. 5. Comparison of protective efficiency of preserving agents by the used environment – *Preservant 2*
(VA – outdoor atmosphere – 100% corroded area, PP – under shelter – 100% corroded area, VM – heated room – no corrosion, NM – unheated room – no corrosion)

DISCUSSION

Relative efficiency of protection provided by preservants exposed to climatic conditions outdoors was 47.237% and 38.875% for Preservant 1 and 2, respectively. Therefore, a statement can be made that none of these preservants is fitted for the conservation of machines and equipments exposed to the outdoor atmosphere. In Preservant 1 (Inkor Bio), the result does not show a good agreement with the manufacturer's recommendation of its use also for the temporary corrosion control up to 10 months. In Preservant 2 (Konkor 437), the result was anticipated since not even the manufacturer recommends its use for such a long-term corrosion control.

Relative efficiency of protection provided by preservants exposed to impacts of outdoor climatic conditions but sheltered was 74.693% and 87.443% for Preservant 1 and 2, respectively. The results indicate that much better values can be achieved by only a partial modification of the storage environment (reduced impact of rainfall, solar radiation, etc.). The two studied preservants exhibited a nearly double increase of relative protective efficiency.

The both preserving agents reached a relative protective efficiency of 100% in Environments 3 and 4, i.e. with the impact of outdoor atmosphere entirely eliminated. This indicates that they can be used both for these types of storage and for a long-term corrosion control.

The effect of environment on the rate and extent of corrosion was demonstrated. It follows out from Table 1 and Figs. 4 and 5 that the relative protective efficiency was markedly variable according to the conditions in which the samples were stored. Samples exposed under the shelter achieved better results than samples exposed to the impact of outdoor climatic conditions; samples exposed in heated and unheated rooms did not exhibit any corrosion at all. For a long-time storage of materials, machines and equipment with using these preservants it is therefore necessary to prevent the access of outdoor atmosphere and harmful substances contained in it or to use preserving agents with a higher relative protective efficiency.

Agricultural buildings and facilities largely differ from the common ones in the enormously aggressive environment (animal production facilities) or in the fact that they are used to store aggressive chemicals (stores of chemical fertilizers) and satisfactory results cannot be achieved even by preventing the access of outer atmosphere. Here it is worth pointing out that hardly any agricultural enterprise is concerned with the protection of their machines and equipments against corrosion and it is therefore adviced to consider whether their untimely damage or devaluation cannot be prevented by proper storage and conservation. The costs of preserving agents are negligible as compared with the costly machines and considerable savings can be made on repairs etc. A comparison of Fig. 1 with Figs. 2 and 3 reveals at the very first sight that the corrosion of unprotected surfaces is much more intensive than that of surfaces which are protected with a preserving agent. A good combination of environment and preserving agent can provide an even 100% relative protective efficiency.

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Received for publication May 28, 2002
Accepted after corrections December 20, 2002

Antikorozní účinnost konzervačních prostředků pro zemědělskou techniku

ABSTRAKT: V práci bylo provedeno srovnání vybraných konzervačních prostředků proti korozi na základě výsledků zkoušek v provozních podmínkách. Odolnost materiálu proti napadení korozí se výrazně mění podle provozních podmínek a vlivu vnějšího prostředí. Nejdůležitějšími faktory ovlivňujícími rychlost koroze je obsah SO_2, teplota a vlhkost. Relativní ochranná účinnost konzervačních prostředků byla stanovena na základě hmotnostních úbytků nechráněných a chráněných vzorků. Zjistili jsme, že odolnost materiálu proti korozi je významně závislá na podmínkách skladování (SO_2, teplota a vlhkost atd.) a samozřejmě na kvalitě použitého prostředku. Hodnoty relativní ochranné účinnosti dosahovaly u prostředku ředitelného vodou 38–87 % podle prostředí a hodnoty relativní ochranné účinnosti u prostředku na rostlinné bázi dosahovaly 47–75 % podle prostředí.

Klíčová slova: konzervační prostředek; odolnost proti korozi; relativní ochranná účinnost; korozní zkouška

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