

CORROSION INVESTIGATION OF PRINTING MACHINES BY FT-IR SPECTROSCOPY

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Original scientific paper

With introducing the environmentally acceptable solutions in printing systems, the effect of corrosion of machine elements becomes more aggressive, unknown and unpredictable, which partly or completely disables long-term exploitation and amortization of printing machines. In this paper, the influence of conventional and ecological fountain solution concentrates was analysed during 31 months, as well as the influence of dissolved compounds from the paper surface on the corrosion of carbon steel. The rate of corrosion in the observed systems was quantified with gravimetric method, while it was qualified with FT-IR spectroscopic method. Transmission FT-IR spectra were recorded for the starting solutions and corrosion products. It was shown that the compounds from the paper surface, dissolved during the printing have the most significant influence on the course and dynamics of corrosion in the printing systems.

Keywords: corrosion, offset printing, fountain solution, FT-IR spectroscopy

Analiza korozije tiskarskih strojeva FT-IR spektroskopskom metodom

Izvorni znanstveni članak

Uvođenjem ekološki prihvatljivijih otopina u tiskarke sustave pojava korozije strojnih dijelova postaje znatno agresivnija, nepoznata i nepredvidiva što otežava ili u potpunosti onemogućava dugotrajno iskorištavanje i amortizaciju tiskarskih strojeva. U ovom radu analiziran je utjecaj konvencionalnih i ekoloških koncentrata otopina za vlaženje te utjecaj otopljenih spojeva s površine papira na koroziju ugljičnog čelika. Proces korozije praćen je kroz 31 mjesec. Dinamika korozije u promatranim sustavima kvantificirana je gravimetrijskom metodom, a kvalificirana je FT-IR spektroskopskom metodom. Snimljeni su transmisijski FT-IR spektri početnih otopina i korozijskih produkata. Iz istraživanja proizlazi da najznačajniji utjecaj na tijek i dinamiku korozije u tiskarskim sustavima imaju spojevi s površine papira otopljeni tijekom tiska.

Cljučne riječi: korozija, ofsetni tisak, otopina za vlaženje, FT-IR spektroskopija

1

Introduction

Corrosion is every unintentional destruction of construction materials, most commonly caused by physical and chemical agents [1]. In the use of printing machines wearing is to a great extent caused by friction between machine parts, as well as under the influence of agents with which they are in contact (lubricants, condensed water, used solutions, washing agents, etc. [2].

Parts of the printing machines are built of different kinds of steel, depending on mechanical-chemical conditions to which they are exposed during the printing process. Additionally, each manufacturer uses specific, mainly patent protected steels or steel alloys for machine parts. From the corrosion aspect, the offset printing system - as a dominant printing technique - is specific because machine parts during the operation come in contact with agents of different physicochemical characteristics. According to available data, the fountain solution is most corrosive among them [3]. Besides basic components (alcohols, hydrophilization salts, salts for regulation of conductivity and hardness), during the printing process ink and surface compounds from the paper surface are dissolved in the fountain solution as well [4]. It is difficult to determine the grounds of corrosion processes developing under such complex conditions; in this investigation, therefore, the steel was exposed to the solutions of systematically changed composition in order to follow the influence of certain parameters on corrosion processes.

All parts of offset printing machines are of high quality production, with very low allowed tolerances; therefore, even micrometric changes will significantly influence the quality of prints. Lowest traces of corrosion

products in bearings of cylinders will cause vibrations of machine parts, while traces of corrosion products on cylinders (base, offset and printing) will cause sliding higher than expected.

In order to follow separately the influence of fountain solutions on corrosion, the laboratory steel (DIN Ust. 12) was used. According to the available data from the manufacturer, the steel used is nearly of the same composition as the one used for construction of cylinders with which the fountain solution is in contact [5]. With a great degree of probability, it can be assumed that the rate of corrosion described in this paper is the same as on steels used for the construction of printing machines. Primary goal of this investigation was to give a contribution to the interpretation of corrosion processes of the steel under the influence of different fountain solutions used in offset printing. However, the steel used in this investigation in the basic composition corresponds to the steels used for construction of machines for other printing techniques; therefore, the results obtained can be applied for the interpretation of corrosion processes in all printing techniques which use paper as a substrate [6].

2

Theoretical background

2.1

Fountain solution

Basic role of the fountain solution in the offset printing process is oleofobisation of non-printing areas on the printing forms. Ink, which is subsequently deposited, is bound to printing surfaces only, and together with the fountain solution is under pressure over rubber blanket transferred onto the printing substrate, in most cases paper.

Besides its basic role, fountain solution passing through the machine and mixing with the ink, enables to define oxypolymerization, defines viscosity, maintaining the temperature of the machine by evaporating, while corrosion inhibitors prevent corrosion of the machine parts. Passing of sheets or web through the machine, surface coating of the paper – due to the friction between the offset and printing cylinders, as well as to the chemical dissolution – enter the fountain solution on the offset cylinder. Subsequently, due to the rotation of machine parts it reaches the remaining cylinders, dampening system and finally, the fountain solution tank. Fountain solution, polluted with dissolved paper coatings, particles of fillers and paper fibres, traces of pigments, etc. has changed properties necessary for printing, thus becoming essentially more corrosive medium.

In conventional alcohol-based dampening systems 2-propanole is primarily used for decreasing the surface tension of the fountain solution; however, it is also well-known corrosion inhibitor [7]. 2-propanole alcohol is very volatile and is considered as a harmful primary and secondary atmosphere pollutant [8]. According to the available data, in conventional alcohol-based dampening systems, to a great extent the effect of corrosion was not generated by the fountain solution [9]. In such systems, corrosion and wearing of machine parts are an inevitable effect, but their rate is known and predictive.

In contemporary offset printing systems of environmentally friendly fountain solutions are developed, which are only to a certain extent influencing the environment. These concentrates are aggressive media, but observed from the technological aspect, a more significant problem is that the corrosion rate in such system is unknown and unpredictable. It is therefore necessary in further development of offset printing to investigate the influence of parameters of fountain solutions (chemical, electrochemical, physicochemical, and mechanical) on corrosion of the machine parts.

2.2 FTIR spectroscopic method

Infrared spectroscopy registers changes in energy of vibration and rotation caused by electromagnetic radiation in the wavelengths range between 0,78 and 1000 μm . The entire range of infrared is arbitrary divided into near, mid and far region, as presented in Tab. 1.

Table 1 Sections of infrared emission and corresponding energy transitions

| Region | $\lambda / \mu\text{m}$ | $\tilde{\nu} / \text{cm}^{-1}$ | Energy transition |
|-----------------|-------------------------|--------------------------------|---------------------------------|
| Near | 0,78 ÷ 2,5 | 12 800 ÷ 4000 | Overtone or harmonic vibrations |
| Mid | 2,5 ÷ 50 | 4000 ÷ 200 | Rotational-vibrational |
| Far | 50 ÷ 1000 | 200 ÷ 10 | Rotational |
| Most common use | 2,5 ÷ 15 | 4000 ÷ 670 | |

Use of wave number instead of wavelength is common in infrared spectroscopy, where it is reciprocal value of wavelengths. Wavelength (λ) and frequency (ν) are inversely related:

$$\nu = \frac{c}{\lambda}, \quad (1)$$

where:

c – speed of light (3×10^{10} cm/s)

ν – frequency, Hz.

For practical reasons wave number has the unit of reciprocal centimetre, so it is:

$$\tilde{\nu} (\text{cm}^{-1}) = 1/\lambda (\text{cm}) = 10^4/\lambda (\mu\text{m}). \quad (2)$$

Since energy and frequency are proportional it results in:

$$E = h \cdot \nu = h \cdot \frac{c}{\lambda} = h \cdot c \cdot \tilde{\nu}, (\text{J}). \quad (3)$$

Thus E (1 eV) \rightarrow 80868 cm^{-1} .

The principle of IR spectroscopy is based on absorption of IR radiation (energy) in a molecule. The IR radiation will be absorbed if the frequency of radiation matches the vibrational frequency of the molecule. A condition for absorption of infrared radiation is change of the dipole moment. Absolutely symmetrical molecules do not show this change, i.e. do not show absorption in the infrared region of electromagnetic radiation. So, for instance, only water and carbon dioxide can be detected in the components of air. Absorbed energy is used on increasing the amplitude of vibration, resulting in absorption maximum or transmission minimum in infrared spectrum [10].

FT-IR spectrometers are also known as interferometric spectrometers, because their most important part is Michelson's interferometer. All emission wavelengths are measured at the same time. Michelson's interferometer operates on the principle of separation of the IR-beam into two parts – one ($\sim 50\%$ of the intensity) reflects from the fixed mirror, while the other one (remaining 50%) is reflected from the movable mirror. Shifting of the movable mirror causes difference in the optical path between the two interfering beams, merging again into one single IR beam. So recombined IR beam transits through the examined specimen, finally reaching the detector. Position and shifting of the movable mirror is controlled by He-Ne laser, which enables high accuracy of frequencies. Obtained interferograms of the reference beam and the beam passed through the specimen are independently transferred by the Fourier transformation into the absorption spectra. FT-IR spectrometers have great advantages compared to classical infrared spectrometers. These advantages are higher passing of the energy in far infrared region, high speed recording, significantly improved relation signal/noise, high resolution and high sensibility of detection.

3

Experiment

3.1

Measuring methods

Change of the mass of steel samples was measured by analytical balance (prod. Mettler) with measurement

accuracy of 10^{-5} g. The dynamics of corrosion can be easily quantified by this method, as well as the loss of material in determined time.

In preparing pastilles for FT-IR spectroscopy measurements specimens of corrosion products were separated from the electrolyte using a high-speed centrifuge Sorvall.

FT-IR transmission spectra were recorded at room temperature with Perkin-Elmer spectrometer, model 2000 (operation range $7800 \div 100 \text{ cm}^{-1}$, resolution 1 cm^{-1}). Finely chopped specimens were compressed into KBr pastilles with the Carver press. For preparation of KBr pastilles, spectroscopically pure KBr was used. Prepared specimens were recorded in mid ($4000 \div 400 \text{ cm}^{-1}$) and far ($700 \div 200 \text{ cm}^{-1}$) infrared range. Operation of the FT-IR was controlled by IRDM program, which at the same time enables the processing of the spectra.

3.2

Preparation of specimens

3.2.1

Treatment of the electrodes

In this investigation the laboratory carbon steel was used ($C_{\max} 0,12 \%$, $Mn_{\max} 0,50 \%$, $P_{\max} 0,04 \%$, $S_{\max} 0,04 \%$), with electrodes cut out from a single plate of area cca 1 m^2 and $0,7 \text{ mm}$ thick. Steel specimens were cut out in dimensions of $60 \times 70 \text{ mm}$. Surface of specimens was treated with grinding paper T 400 and T 800, furthermore highly polished with the polishing paste. After mechanical treatment, specimens were for 5 minutes immersed into undiluted acetone, shortly immersed in water and for 10 seconds decapitated in 10% water solution of sulphuric acid. After two minutes of washing in distilled water and drying in the air, specimens were immersed into the electrolyte. Uniformity of surface treatments was checked with the spectrophotometer and on all repaired specimens the same spectral re-emission was recorded.

3.2.2

Preparation of electrolytes

In real printing processes demineralized and deionized water is used to prepare the fountain solution [11]. It can be assumed that the components remaining in the water after demineralization and deionization do not influence significantly corrosion processes; in this investigation, therefore, freshly opened distilled water was used produced by INA-Maziva d. d. according to ISO 9001, ISO 14001 and OHSAS 18001, as to exclude influence of starting parameters of water (firstly its pH value) on corrosion processes.

Solutions of paper surface compounds were prepared in order to reliably simulate real conditions in printing processes. Samples of paper for sheet-fed printing were cut into strips of $460 \times 60 \text{ mm}$ and ten of the strips of each paper were immersed into 500 ml of the prepared electrolyte for 5 seconds. Construction of vessels enabled full contact of paper surface with the solution, without touching each other. Within this short period only primary penetration of the electrolyte occurs, therefore only surface compounds from the surface were dissolved. In this way real conditions of offset printing are simulated,

where such dissolution takes place in the contact of the offset cylinder with the paper [12]. In preparing the electrolytes ten paper strips were immersed because electrical conductivity increased for the value measured in real printing conditions, without addition of buffer and solution for the regulation of hardness. Therefore, although chemical composition of the dissolved compounds is not completely known, it can be stated that the ions dissociates from the paper surface are qualitatively and quantitatively nearly the same as under real printing conditions. Through further investigation all samples of different papers were treated in the same way.

First electrolyte (hereinafter referred to as S1) is a conventional fountain solution with the addition of 2-propanole alcohol, which did not show significant corrosion phenomena in real printing conditions. 500 ml of the solution was prepared, containing 3% of alcohol buffer "Fountain solution Blue 3300" prod. Vegra and 3% of 2-propanole.

Second electrolyte (hereinafter referred to as S2) is an ecologic solution intended for non-alcoholic dampening, showing corrosion in real printing conditions. 500 ml of the solution was prepared, containing 3% of the buffer "Alco-Damp RED 3232/870 Zi dH N" prod. Vegra.

For the preparation of the third and fourth electrolytes, $10\,000 \text{ ml}$ of starting solution was made ready. In the vessel of 500 ml compounds from the paper surface were dissolved according to the procedure already described.

Third electrolyte (hereinafter referred to as S2P1) is a solution of surface compounds of a gloss coated sheet-fed printing paper 120 g/m^2 prod. Euro Art (hereinafter referred to as P1) in the ecologic solution.

Fourth electrolyte (herein after referred to as S2P2) is a solution of surface compounds from uncoated paper for sheet-fed printing 80 g/m^2 , prod. Tauro (hereinafter referred to as P2) in ecological solution.

After stirring (without decanting) 350 ml of the electrolyte was poured out from the vessel in which it was prepared into another one, with the steel sample immersed in it and finally sealed.

The investigated systems were closed in order to prevent evaporation of the compounds from the electrolyte, as well as the chemical influence from the environment.

According to the data obtained from the vendor, kinds of paper used in this investigation are among the most represented on the regional market for sheet-fed printing.

4

Results

Fig. 1 shows changes of the mass of the steel samples immersed into electrolytes S1, S2, S2P1 and S2P2 after the removal of corrosion products in the period of 31 months.

According to expectations the loss of mass in the observed systems is extraordinary small, taking into consideration long time of exposition of steel samples in the electrolytes and their relatively high mass (cca 22 g).

In each observed system a successive loss of mass occurs with the course of the corrosion process. Contrary

to the expectations, the least loss of mass was measured in the electrolyte S2, while much higher loss of mass was measured in the electrolyte S1.

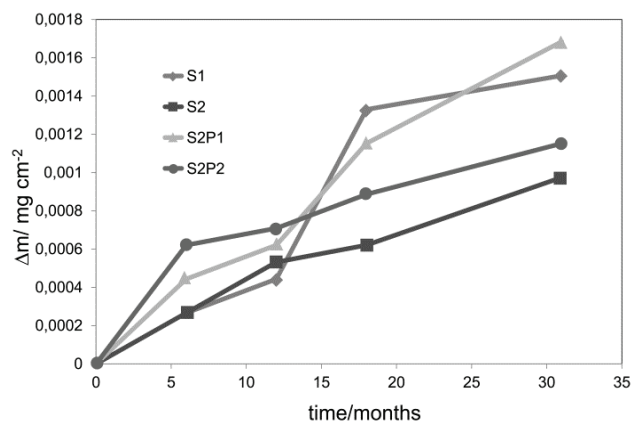


Figure 1 Change of mass of steel sample after removal of corrosion products, immersed into the electrolytes S1, S2, S2P1 and S2P2 during the period of 31 months

According to expectations and earlier investigations in the electrolyte systems higher loss of mass was measured in electrolytes with the dissolved compounds from the paper surface (S2P1 and S2P2) than in the starting electrolyte without dissolved compounds from the paper surface.

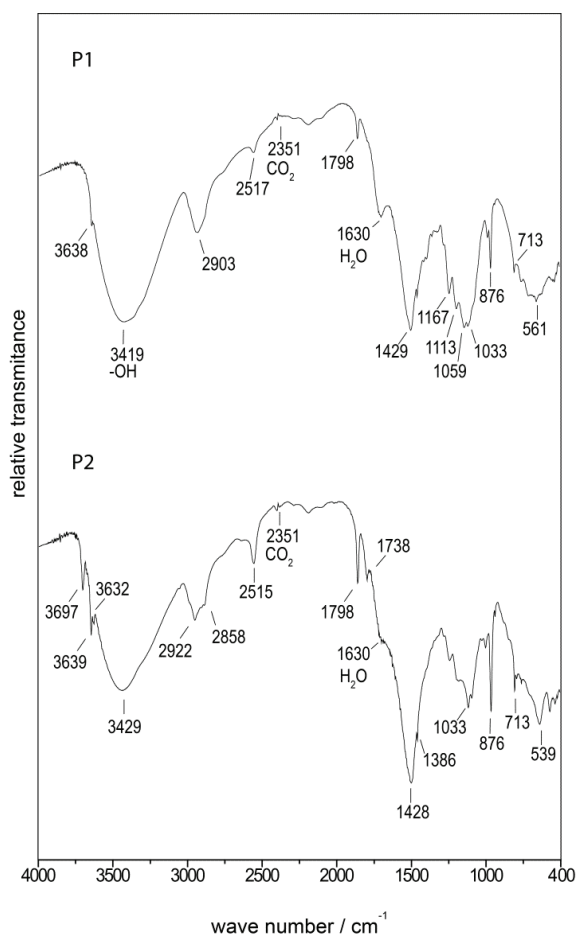


Figure 2 FT-IR spectra of paper P1 and P2, recorded at the room temperature

Since earlier investigations showed significant influence of surface compounds on the rate of steel corrosion in distilled water [13], this investigation is

tracking the influence of real fountain solutions – prepared according to the instructions of the manufacturers – as well as the influence of the compounds from the paper surface dissolved in the ecologic solution on steel corrosion.

FT-IR spectra of starting sample paper of P1 and P2 are shown in Fig. 2.

Two types of the fountain solution were used: conventional solution, intended for alcohol dampening (S1) and ecologic solution, intended for non-alcohol dampening (S2). FT-IR spectra of these solutions are presented in Fig. 3.

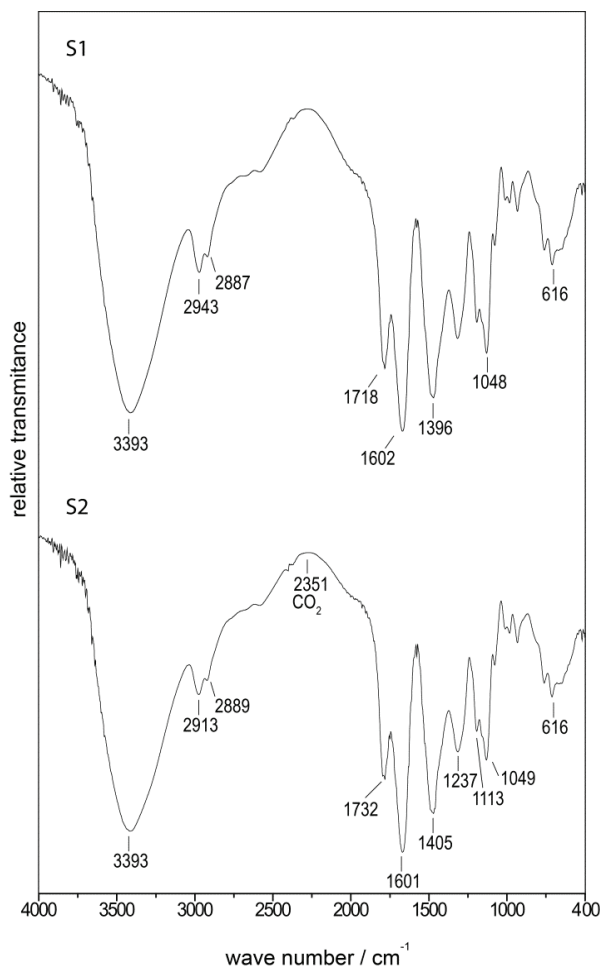


Figure 3 FT-IR spectra of sediments of electrolytes S1 and S2 recorded at the room temperature

It should be mentioned that either fountain solution gives identical FT-IR spectra, they - as well as FT-IR spectra of the paper, are used only as the reference in the identification of IR band of corrosion products. Therefore, the detailed analysis of FT-IR spectra for fountain solutions has not been carried out. For the same reason, FT-IR spectra of the electrolytes S2P1 and S2P2 as the starting solutions, were recorded. Corresponding FT-IR spectra without detailed interpretation are presented in Fig. 4. The corrosion products were isolated and analysed after 1 day, 6 months, 12 months and 31 months of corrosion.

Obtained results can be summarized as follows:

After the first day no indications of corrosion of the examined steel were noticed in any of the fountain

solutions. Corrosion was noticed in the electrolytes S2P1 and S2P2.

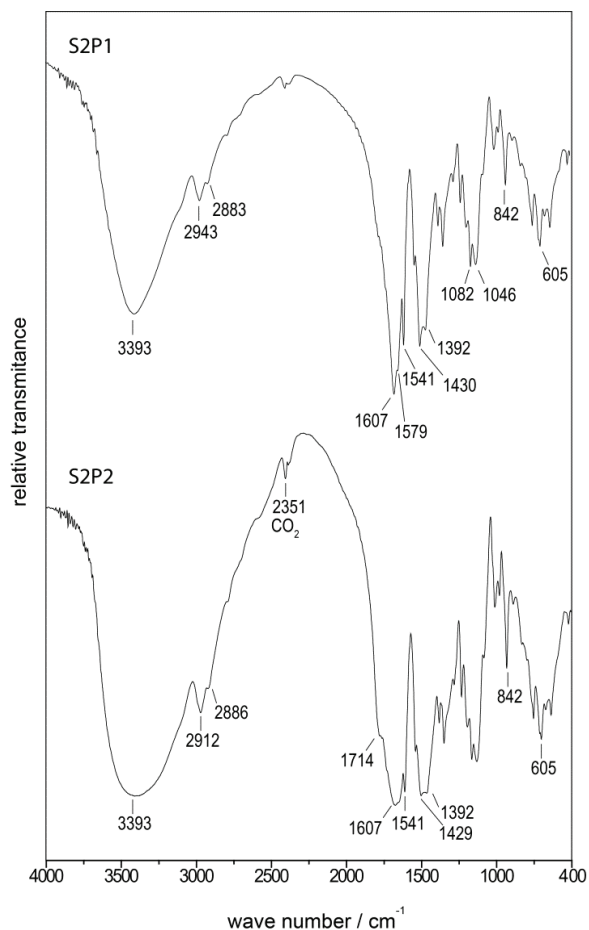


Figure 4 FT-IR spectra of electrolytes S2P1 and S2P2, recorded at the room temperature

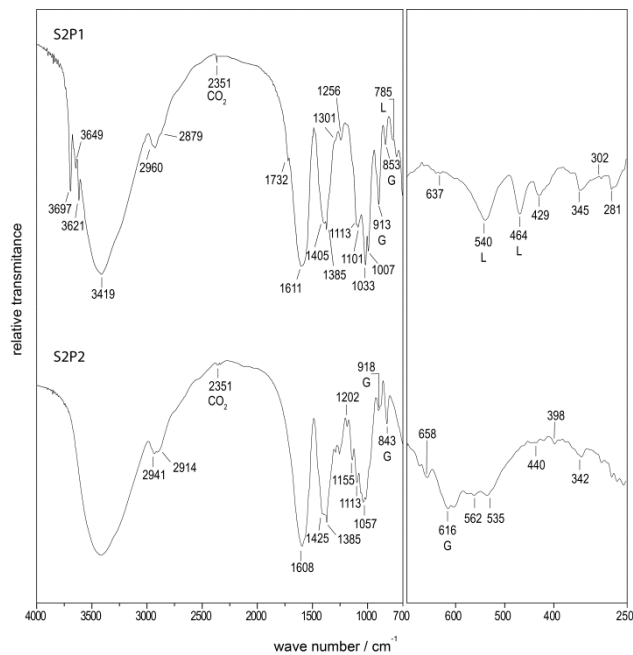


Figure 5 FT-IR spectra of corrosion products of steel in electrolytes S2P1 and S2P2 after 6 months, recorded at the room temperature

Even after 6 months of exposition, no indications of corrosion were noticed in starting solutions S1 and S2. On the contrary, in electrolytes S2P1 and S2P2 the

progression in corrosion process was observed. Isolated products were analysed by FT-IR spectroscopy, with the results presented in Fig. 5.

Corrosion of the examined steel in starting solutions did not advance even after 12 months. Corrosion products were isolated together with the paper particles electrolytes from the systems S2P1 and S2P2. FT-IR spectra of the isolated products are presented in Fig. 6.

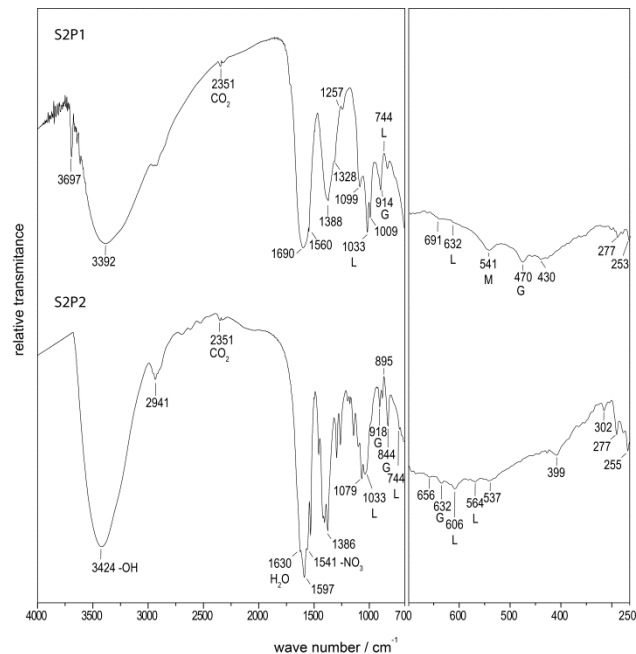


Figure 6 FT-IR spectra of corrosion products of steel in electrolytes S2P1 and S2P2 after 12 months, recorded at the room temperature

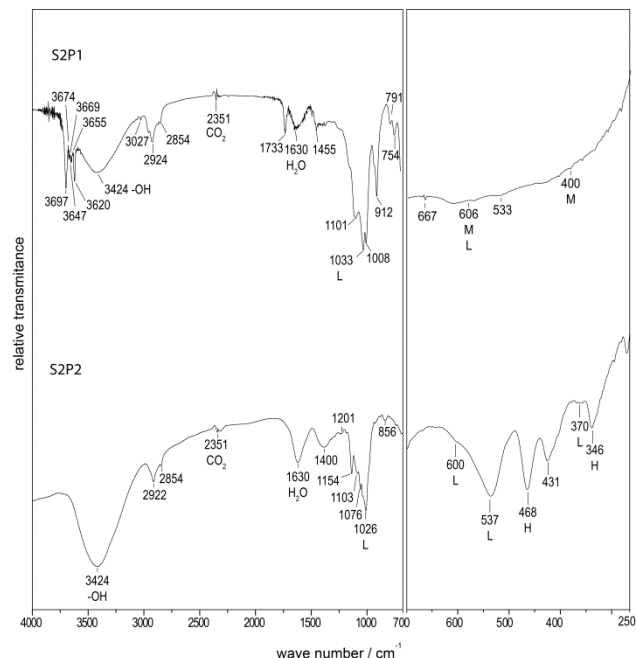


Figure 7 FT-IR spectra of corrosion products of steel in electrolytes S2P1 and S2P2 after 31 months, recorded at the room temperature

Corrosion of the examined steel in starting electrolytes S1 and S2 was noticed only after 31 months, but the yield was insufficient for the instrumental analysis. FT-IR spectra of the corrosion products isolated from the electrolytes S2P1 and S2P2 obtained by the

corrosion of the examined steel after 31 months is presented in Fig. 7.

5 Discussion

The influence of real industrial solutions on corrosion of steel samples was monitored in this investigation during 31 months. Real solutions contain easily evaporating components; therefore the investigation was conducted in the closed system, in which the absorption of oxygen into the electrolyte is disabled as well as evaporation of vaporous components from the electrolyte. Steel used in the experiments, besides iron, contains traces of other elements of different redox potential, while additionally and depending on the composition, electrolytes contain different concentrations of dissolved oxygen. With the immersion of steel samples microgalvanic elements are formed, which are causing corrosion. Since the steel used in all experiments is of the same composition, the rate of the corrosion will depend only on the composition of the electrolyte. Elementary iron in the primary electrode reaction transforms with oxidation into iron(II) ions. Furthermore, primarily depending on the concentration of oxygen and hydroxyl ions in the electrolyte, iron(II) ions in the secondary and tertiary reactions form oxides, oxihydroxides and hydroxides of iron, thus forming different crystal structures (ghetite, lepidocrocite, hematite, magnetite, maghemite, akagenite ...), depending on the physicochemical circumstances in the electrolyte. So formed compounds on the surface of steel are of the porous structure, collapsing from the surface, thus reducing the mass of the sample. Overall dynamics of corrosion in single electrolyte as a function of time can be registered by precise measurement in decrease of the mass of the steel samples.

Coatings on the paper give the necessary surface visual and physicochemical characteristics, which are different depending on the sort of paper, where each manufacturer developed patent protected compounds for the treatment of the paper surface. During the process in the tribological system between the offset and printing cylinder, wet friction occurs, which causes dissolution of the compounds from the paper surface. Such dissolved compounds of different chemical origin in the system with the fountain solution – which is by itself of complex composition – an extremely complex corrosion system will be generated [14]. In the real conditions of printing, the starting parameters of fountain solutions do not act as an aggressive corrosion media, but during the printing process with the dissolution of the surface coatings of the paper and with the influence of the printing ink on the fountain solution, their composition is changed, thus becoming a significantly more aggressive medium. In preventing the corrosion of the printing machines it is necessary to track and control chemical composition of the paper and the ink entering the printing machine, because just these attributes will have the most significant influence on the rate of the corrosion [15, 16].

Chemical composition of paper depends on its type. All kinds of paper contain organic and inorganic ingredients, whose content depends on the application of

the paper. Organic components are cellulose, hemicelluloses, lignin and its compounds, the content of which varies between 70 and 100 %. Inorganic components are mostly different fillers, like calcium carbonate, calcium hydroxide, clays, titanium dioxide etc. Small differences in performance of FT-IR spectra, shown in Fig. 3 can be attributed to the differences in basic chemical composition of gloss coated and uncoated paper, i.e. in different content of inorganic fillers and/or different content of organic ingredients in paper. FT-IR spectra of both types of paper show bands characteristic for cellulose. IR bands centered at 3419 and 3429 cm^{-1} correspond to the stretching vibrations of –OH groups, while IR bands at 2900 cm^{-1} correspond to stretching vibrations of –CH groups. Deformation vibrations of –CH, –CH₂ and COH groups correspond to IR bands in the range of wave numbers of 1200 to 1500 cm^{-1} , while IR bands noticed in the range between 1200 and 1400 cm^{-1} correspond to the vibrations of C atoms or to deformation vibrations of –OH groups. IR band at 1630 cm^{-1} corresponds to the bending vibrations of –OH groups of the adsorbed molecules of H₂O. This band is significantly more intense in the FT-IR spectra of gloss coated paper samples, which indicates a greater quantity of adsorbed water related to the uncoated paper [17].

Corrosion products isolated from the solutions after 6 months shown in Fig. 5 of corrosion of examined steel are a mixture of corrosion products and paper particles. For that reason sharp IR bands of high intensity are visible in the related FT-IR spectra, corresponding to the vibrations of the paper molecules, i.e. cellulose. In relation to the referent IR spectra of the paper and the fountain solution, the new IR bands centered at ~ 850 and ~ 785 cm^{-1} were noticed, which can be attributed to the ghetite. In the far IR range of FT-IR spectra the paper and the fountain solutions did not show the strong IR bands, therefore the appearance of IR bands at ~540, 464, ~400 and ~345 cm^{-1} can be attributed to the corrosion products, gohetite, lepidocrocite and/or magnetite. Very strong and wide IR band centered at 1057 ÷ 1033 cm^{-1} – characteristic for lepidocrocite – is also present in the referent FT-IR spectra of the paper and the fountain solutions. On the other side, weak IR band at ~744 cm^{-1} could be an indicator of the presence of lepidocrocite in the corrosion products obtained by corrosion of the examined steel in electrolyte S2P1.

FT-IR spectra of the corrosion products isolated from electrolytes S2P1 and S2P2 obtained by the corrosion of the examined steel after 12 months, presented in Figure 6., are showing that along with the IR bands characteristic for the paper and fountain solutions – new IR bands can be noticed, which can be attributed to gohetite (~890 i ~785 cm^{-1}). Appearance of IR bands at 564, ~540 and ~400 cm^{-1} indicate the possible presence of lepidocrocite and magnetite. Possible presence of lepidocrocite is additionally indicated with the new IR band at 744 cm^{-1} .

FT-IR spectra of corrosion products obtained by the corrosion of the examined steel in electrolytes S2P1, presented in Fig. 8, points out that IR bands in the far IR range are much more intense, however the quantitative phase analysis of corrosion products based only on IR spectroscopy cannot be reliable because of possible

overlapping of characteristic IR vibrations of lepidocrocite, hematite and magnetite.

There is an analogy between the corrosion of steel in water solutions and precipitation of iron oxides from aqueous solutions of Fe-salts. The term iron oxides indicates iron oxides, oxihydroxides and hydroxides. Kinetics of precipitation and phase composition of iron oxides depend on the experimental parameters, such as the type and concentration of Fe salts, pH, temperature, the time of ageing, ionic strength, presence of foreign anions and cations, organic molecules, surface active substances and polymers. In the first stage of precipitation of iron oxides, the hydroxy complexes are formed, which in oleation reactions give hydroxy polymers, while in oxolation reactions oxo-bridges are formed with visible solid phase. Iron oxides are undergoing different phases transformation during the process of precipitation by mechanisms of dissolution/recrystallization or by mechanism of direct structure re-arrangement. Precipitation from the aqueous solutions of FeCl₃ salts at low pH values yields the formation of akagenite (β -FeOOH) particles, while the precipitation from aqueous solutions of FeNO₃ under equal conditions gives particles of goethite. On the other hand, the particles of lepidocrocite (γ -FeOOH) will precipitate from aqueous solutions of Fe(ClO₄)₃. At increased temperatures particles of hematite are formed (α -Fe₂O₃), regardless of the anion type present in the solution. Magnetite (Fe₃O₄) will precipitate from Fe(II) salts precursors under protective inert gas atmosphere. Addition of different additives (metallic cations, anions and polymers) into the precipitation system may inhibit or promote the precipitation process. This investigation has shown that the corrosion of the examined steel in aqueous solutions substantially depends on physicochemical parameters of corrosion: type of the electrolyte, pH value and the presence of additives. Earlier investigations have proved that the corrosion of the examined steel in distilled and tap water at room temperature is a quick process, while the corrosion at the room temperature in starting solutions, conventional (S1), as well as ecologic (S2), is almost completely inhibited. It was also shown that the corrosion of the examined steel in ecologic fountain solution systems, with the presence of the compounds from the paper surface, was significantly accelerated in respect to the starting system. Small differences noticed in the phase structure of the corrosion products, related to the sort of paper present in the solution, can be related to the different chemical composition of the paper.

6

Conclusions

From the conducted investigation, the following can be concluded:

The effect of corrosion is imminent in the processes of graphic reproduction, especially in offset printing, where certain machine parts are exposed to the influence of the fountain solution. Corrosion can affect operation of some systems, which – as a consequence – causes problems in functioning of the printing press and poor quality of the prints. Along with the fountain solutions – which can be of different character and complex

composition – a significant influence on the effect, intensity and rate of corrosion have the dissolved compounds from the paper surface.

With systematic tracking of the mass loss of steel samples within a longer period (31 months) in fountain solution and in presence of dissolved compounds from the paper surfaces, corrosion was inevitably proved, i.e. formation of the corrosion products occurred.

In contact with real fountain solutions, with the added corrosion inhibitor, the corrosion rate of steel samples was significantly decreased.

It was affirmed that the ecologic fountain solution in the entry state is a less corrosive medium than the conventional alcohol solutions. From the results obtained and analysis performed it can be concluded that the ecologic fountain solution becomes chemically more aggressive only in the presence of the dissolved compounds from the paper surface.

Laboratory simulations of real system performed in this investigation gave an insight into corrosion processes for the solutions and the paper selected in this study. Since coatings of different chemical compositions are applied in the processing of the paper, it can be assumed with great probability that the majority of uncoated and gloss coated kinds of paper of different origin will have similar influence on the rate of the corrosion processes in real circumstances of offset printing.

Depending on the sort of paper, and firstly on the kind of surface compounds, which are transferred in the fountain solution by dissolution, the rate of corrosion processes in offset printing systems is substantially different. From the analysis performed and the results obtained it can be with a high degree of probability stated that the corrosion processes in the systems of graphic reproduction are in direct correlation with the kind of compounds on the paper surface.

Finally, it can be concluded that in the examined systems of the ecologic fountain solutions, the dissolved compounds from the surface of gloss coated paper show the largest influence on the rate of the corrosion process.

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