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Forecasting of durability of waterborne coatings in the machine industry

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ABSTRACT

Purpose: The paper presents the problems of forecasting of durability of waterborne acrylic coatings and epoxy coatings designed to protect devices and machine elements.

Design/methodology/approach: The durability forecast has been performed on the basis of analyses of time series with the use of trend function extrapolation. Mechanical properties such as: scratch resistance, impact strength, grindability and luster have also been evaluated. Moreover, besides standardized methods, some complementary methods have been applied in the form of analyses of microscopic images of damage caused by the exposition of coatings to corrosion.

Findings: Assuming five-year durability for coatings on devices and machine elements (time between overhauls), one can find that investigated waterborne coatings can be a successful protection of devices and machine elements in the established range and in the dependence on the applied system.

Research limitations/implications: The research has shown some substantial influence of coating system width changes on obtained results of scratch resistance and impact strength. It should be beneficial to extend further research with the description of the mechanism that enables to obtain some strict correlation between the investigated properties of coatings and the allowance of their width.

Practical implications: The research makes possible to determine the areas of application for coatings obtained from waterborne materials to anticorrosion protection of devices and machine elements. This enables to eliminate gradually traditional solvent coatings (of high VOC content), which are disadvantageous to the environment.

Originality/value: The applied sequence of research can form a proposal of the method to evaluate coatings made of some other than investigated waterborne materials predestinated for machine industry.

Keywords: Mechanical properties; Forecast; Durability; Waterborn coatings

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PROPERTIES

1. Introduction

Paint coatings have many and unique advantages and one substantial disadvantage that is related to the fact that the sector of organic protection coats is the source of huge emission of volatile compounds to the atmosphere. That is why, there is a necessity to replace solvent materials (of high VOC content) widely used in machine industry, with other materials of low harmfulness to the environment. Waterborne paints seem to be particularly advantageous and their recipes are improved every year [1-7, 11].

Unfortunately, the application of waterborne materials to anticorrosion protection systems for devices and machine elements still gives rise to controversy [12, 17].

There is no detailed analysis and research methodology for these coatings in the context of their use in machine industry. This is required with some particular attention to the analysis of mechanical properties that are decisive to the usefulness of coating. The changes of these properties in operation life prove the level of destruction of binding material and the reduction of protective properties. That is why the problem described in the paper related to the determination of the range of changes for mechanical selected properties in the result of climatic conditions is very important because of safe operation of examined coating systems used particularly in the machine industry. The total influence of solar radiation, rain, fog, frost and atmospheric pollution at daily or seasonal intensity changes provides an extensive knowledge of protective properties of a particular coating system. The analysis of time series can be used to discover the nature of investigated phenomena (i.e. mechanical properties) and the waveform of their time changes. In relation to the problems mentioned in the paper, time variables enable some description of the influence of ageing time of coatings exposed to corrosion on the changes of examined properties without the necessity to introduce non-measurable factors such as temperature and humidity of the experimental environment to mathematical models. In general approach, the phenomena described by means of time series are a resultant from main factors and adventitious (random) factors. After a relatively long period of measurements, the action of main factor causes the emergence of a development tendency for the examined phenomenon, i.e. trend (coating degradation). Linear trend models are used in most cases which enables to determine a forecast range and its precision in the consequence [9, 15]. Summing up on the basis of tests of selected mechanical property changes of exposed samples some conclusions of coating durability can be derived.

2. Studied coating systems

Coatings designed for different construction elements should have numerous advantageous physical, chemical and mechanical properties, high corrosion resistance and chemical resistance (Table 1). All these properties should be in consistence with low harmfulness for the environment. The materials presented in Fig. 1 has been selected on the basis of the reference literature, standards and paint material market. The main criterion of division for paint materials is resin that has prevailing importance for final properties of obtained coating [1-8, 10, 11, 13, 14, 17].

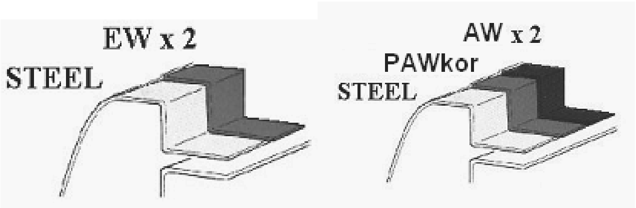

Fig. 1. Studied coating systems (x2 - double layer – thickness of the layer: 25±5μm)

Table 1.
Characteristics of the coatings

Coating	Characteristics	Technical data
PAWkor	Waterborne anti-corrosive acrylic undercoat. It serves to protect steel, zinc steel against corrosion	• Drying time: I degree -8h (20 °C)
AW	Waterborne acrylic enamel. It serves as a priming paint to any base	• Drying time: I degree - 2 h (20 °C)
EW	Two-component waterborne epoxy paint. It contains anti-corrosive pigment (zinc phosphate) It serves as a priming paint or surface coating to protect steel	• Components ratio base: hardener 50:50 volume. • VOC: 40 g/l • Drying time: • I degree - 1 h (23 °C)

3. Methods of examination

The test samples with applied coatings were placed in a stack inclined at 45° (temperate climate) and south oriented with no shield to destructive conditions [16].

The exposition period at climatic station was 6 months (180 days and nights – from October to April) and the coated plate samples were in an industrial zone of Silesia (Zabrze, Poland). The observation was performed once a month (every 30 days) during the tests. The state of coating surface was established on the evaluated gloss and such properties as scratching resistance, impact resistance, abrasion resistance (Table 2). The gloss can be treated as a kind of degradation meter for a coat surface because within the wear from humidity, temperature, atmospheric oxygen and UV radiation, the surface reduces its ability to reflect light. That is why, the value of gloss determines the level of coat surface damage. However, because of very low gloss of epoxy coatings (about 3-5%), only acrylic coating gloss was registered during the exposition.

Table 2.
Methods of examination

Features examined	Standard	Method descriptoin
Gloss	PN-EN ISO 2813:2000	Glossmeter (Evans Elektroselenium)
Scratch resistance	PN-EN ISO 1518:2000	Clemen's apparatus
Impact resistance	PN-EN ISO 6272:1999	Falling weight test (Du Pont)
Abrasion resistance	PN-80/C-81539	Free-falling of abrasive material
Microscopic image	-	Optical microscope (Carl Zeiss Jena)

The statistical analysis of time series has been used to discover the nature of examined phenomena in time and to perform the forecast [7]. Trend function linear extrapolation has been applied according to the formula:

$$\hat{y}_t = a\cdot t + b \tag{1}$$

where:

$$a = \frac{n\sum_{t=1}^{n} y_t t - \sum_{t=1}^{n} y_t \sum_{t=1}^{n} t}{n\sum_{t=1}^{n} t^2 - \left(\sum_{t=1}^{n} t\right)^2} \tag{2}$$

$$b = \bar{y}_t - a\cdot \bar{t} \tag{3}$$

where: $\hat{y}_t$ - predicted values on the basis of matching model; y_t – observed values; n – number of measurements (observations); t - time; $\bar{t}$ - arithmetic mean of increasing values t; $\bar{y}_t$ - arithmetic mean of observed values;

The parameter z_t has been introduced to eq.(1) to match the model to observed values

$$\hat{y}_t = a\cdot t + b + z_t \tag{4}$$

This parameter represents the variability that is not explained by the model. The better the model reflects the data structure, the remainders are smaller.

$$z_t = y_t - \hat{y}_t \tag{5}$$

where: z_t – the remainder, i.e. the difference between the observed values y_t, and the computed (predicted) values $\hat{y}_t$ on the basis of the matching model.

Next, standard errors have been computed for trend linear function parameters and for predicted value:

$$\bar{\sigma}_a = \frac{\sigma_z}{\sqrt{\sum_{t=1}^{n} t^2 - n\bar{t}^2}} \qquad \bar{\sigma}_b = \sigma_z \cdot \sqrt{\frac{\sum_{t=1}^{n} t^2}{n\left(\sum_{t=1}^{n} t^2 - n\bar{t}^2\right)}} \tag{6}$$

where: σ_z – remainder standard deviation expressed by:

$$\sigma_z = \sqrt{\sigma^2_{z_t}} \tag{7}$$

where: $\sigma_{z_t}^2$ - remainder variance expressed by the eq.:

$$\sigma_{z_t}^2 = \frac{\sum_{t=1}^{n} z_t^2}{n-2} \tag{8}$$

Predicted value standard error:

$$\bar{\sigma}_{\hat{y}_t} = \sigma_z \cdot \sqrt{\frac{1}{n} + \frac{\left(t-\bar{t}\right)^2}{\sum_{t=1}^{n}\left(t-\bar{t}\right)^2}} \tag{9}$$

The next stage of time series analysis is the computation of correlation coefficient. The measure of correlation used at the research is linear correlation coefficient, so called Pearson's correlation coefficient – r, computed from eq.:

$$r_{yt} = \frac{\mathrm{cov}_{yt}}{\sigma_y \cdot \sigma_t} \tag{10}$$

where: cov_{yt} – covariance; σ_y, σ_t – standard deviation of two data sets

$$\mathrm{cov}_{yt} = \frac{1}{n}\sum_{i=1}^{n}\left(t_i - \bar{t}\right)\cdot\left(y_{ti} - \bar{y}_t\right) \tag{11}$$

The last stage is the construction of forecast for 3 months (90 days) of exposition to corrosion of tested coatings. The following forecast has been computed:

$$E\left(\hat{y}_{t=n+\omega}\right) = \hat{y}_{t=n}\cdot\omega a \qquad \omega=1, 2, 3,... \tag{12}$$

Then, the range forecast has been computed, assuming the numerical range that covers the estimated parameter value with probability of 95%:

$$E_p\left(\hat{y}_{t=n+\omega}\right) = (\hat{y}_{t=n}\cdot\omega a) \pm t_\alpha \cdot \Psi_{pT} \tag{13}$$

where: t_α – standardized variable (determined from t – Student distribution tables); Ψ_{pT} – mean error of linear forecast

Additionally, the forecast precision has been evaluated. The evaluation consists in computations of mean forecast error called ex post precision meter:

$$\Psi_{pT} = S_z \cdot \sqrt{\frac{\left(T-\bar{t}\right)^2}{\sum_{t=1}^{n}\left(t-\bar{t}\right)^2} + \frac{1}{n} + 1} \qquad T=n+1, n+2,... \tag{14}$$

4. Results of examination

4.1. Gloss

Because of low gloss on epoxy coatings, only acrylic coatings (AW) have been subjected to the evaluation. Regression equation forms, estimated standard errors and linear correlation coefficients a presented in Table 3.

The average month degradation of waterborne acrylic coating has been found within the range of 0.65-0.68%. Pearson's correlation coefficient has indicated a very strong linear correlation between the change of gloss and exposition time. One can find from the analysis of Table 4 that minimal reminder values suggest that the linear model should reflect the data structure very well.

Table 3.
Linear trend model estimations

	AW
Form of regression equation	$\hat{y}_t$ =-0.68t + 60.37
Standard error of parameters of function trend	$\bar{\sigma}_a$ =0.03 $\bar{\sigma}_b$ =0.11
Correlation coefficient – r	0.99
Standard error of estimation	0.13

Table 4.
Predicted values computed on the basis of a linear trend model

t	n	y_t	$\hat{y}_t$	z_t	$\bar{\sigma}_{\hat{y}_t}$
Period (October-April)	1 (t_1)	59.8	59.7	0.1	0.09
	2 (t_2)	59.0	59.0	0.0	0.07
	3 (t_3)	58.3	58.3	0.0	0.06
	4 (t_4)	57.6	57.6	0.0	0.05
	5 (t_5)	56.8	57.0	-0.2	0.06
	6 (t_6)	56.2	56.3	-0.1	0.07
	7 (t_7)	55.8	55.6	0.2	0.09

Table 5 presents a point forecast of gloss and the range forecast at established confidence interval of 0.95.

Table 5.
Predicted gloss reduction results for the tested coating during 3 months

n	$\mathbf{E}\left(\hat{y}_{t=n+\omega}\right)$	Confidence interval -95%	Confidence interval +95%	Ψ_{pT}
8 (t_8)	54.9	54.6	55.2	0.12
9 (t_9)	54.2	53.9	54.6	0.14
10 (t_{10})	53.6	53.1	54.0	0.17

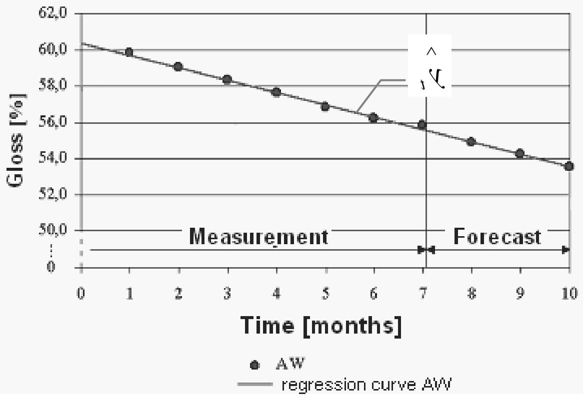

Fig. 2. Course of time series

It can be expected that if the linear trend was maintained, the gloss would be of 53.6% after subsequent 3 months of exposition to corrosion (Fig. 2). The forecast precision is high. Forecast mean error values are about the level of 0.17%. Assuming this short-term forecast with the linear compensation and 50% criterion of reduction for the tested property, one can estimate the waterborne AW coating would reach the minimal established gloss (within the range of 28-30%) after 45 months of exposition at climatic station. This means nearly 4 years of safe operation in machine industry.

4.2. Scratch resistance (scratch hardness)

The parameters of linear trend function have been determined. The function approximates the time series terms of predicted variable. Standard errors and Pearson's linear correlation coefficient have been estimated (Table 6).

Table 6.
Linear trend model estimations

	AW	EW
Form of regression equation	$\hat{y}_t$ =15.14 t + 333.57	$\hat{y}_t$ =7.57t + 428.29
Standard error of parameters of function trend	$\bar{\sigma}_a$ =1.53 $\bar{\sigma}_b$ =6.83	$\bar{\sigma}_a$ =1.09 $\bar{\sigma}_b$ =4.91
Correlation coefficient – r	0.98	0.95
Standard error of estimation	8.08	5.81

It can be found from the analysis of Table 6 that the mean month increase of scratch resistance for acrylic coating is above 15 g. The mean error of this estimation is about 1.53 g. Moreover, the correlation coefficient r shows strong linear dependence of examined variable values – scratch hardness of AW coating and time.

In the case of epoxy coatings a half year period had also the influence on the scratch resistance. The linear trend model showed average month scratch hardness increase on the level above 7.5 g but only a little. Thus, the dynamics of scratch hardness increase of EW coating was lower than the one of AW coating.

Then, after the determination of trend function forms, predicted values for particular observation periods have been computed and standard error of this value has been estimated. Some particular attention should be attracted to parameter z_t, when the model is worked out to match observed values (Table 7).

When the parameter z_t and predicted value standard error are analyzed. One can find that in the case of waterborne epoxy coating the linear trend model reflects the data structure in the better way.

The next stage was the formulation of point forecast and range forecast for scratch hardness of waterborne coatings for subsequent 3 months (Table 8).

Table 7.
Predicted values computed on the basis of the linear trend model

t	n	y_t	$\hat{y}_t$	z_t	$\bar{\sigma}_{\hat{y}_t}$
			AW		
Period (October-April)	1 (t_1)	350.0	348.7	1.3	5.5
	2 (t_2)	362.0	363.9	-1.9	4.3
	3 (t_3)	378.0	379.0	-1.0	3.4
	4 (t_4)	386.0	394.1	-8.1	3.1
	5 (t_5)	421.0	409.3	11.7	3.4
	6 (t_6)	431.0	424.4	6.6	4.3
	7 (t_7)	431.0	439.6	-8.6	5.5
			EW		
	1 (t_1)	438.0	435.9	2.1	4.0
	2 (t_2)	444.0	443.4	0.6	3.1
	3 (t_3)	456.0	451.0	5.0	2.5
	4 (t_4)	450.0	458.6	-8.6	2.2
	5 (t_5)	462.0	466.1	-4.1	2.5
	6 (t_6)	472.0	473.7	-1.7	3.1
	7 (t_7)	488.0	481.3	6.7	4.0

Table 8.
The results of forecasting calculations for scratch hardness changes of coatings during 3 months

n	$\mathbf{E}\left(\hat{y}_{t=n+\omega}\right)$	Confidence interval -95%	Confidence interval +95%	Ψ_{pT}
		AW		
8 (t_8)	454.7	437.2	473.3	7.2
9 (t_9)	469.9	448.7	490.9	8.6
10 (t_{10})	485.0	460.2	509.8	10.1
		EW		
8 (t_8)	488.9	476.2	501.5	5.2
9 (t_9)	496.4	481.2	511.6	6.2
10 (t_{10})	504.0	486.2	521.8	7.3

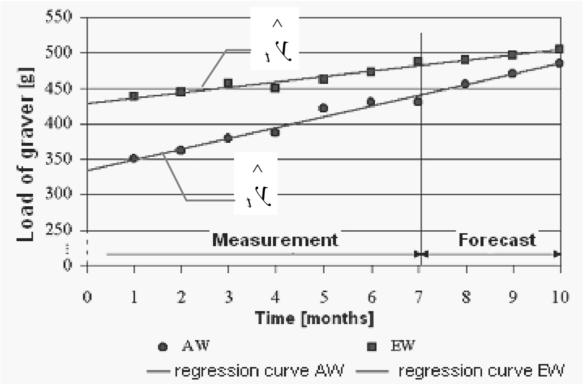

Fig. 3. Course of time series

Assuming the level of confidence at 0.95, one can estimate that the expected value will be not lower than 460.2 g for the AW coating and 486.2 g for the EW coating and not higher than 509.8 g for the AW coating and 521.8 g for the EW coating. This applies to the period of next three months of exposition (Fig. 3). It is worth mentioning that the mean error of the forecast increases systematically the longer forecast period is considered. At the same time its value in the period of 3 months in the case of waterborne acrylic coating system is high (above 10%).

4.3. Impact resistance

In the case of coating impact resistance, only the waterborne acrylic coating has been subjected to the evaluation because the epoxy coating had its impact resistance higher than the boundary limit (50 cm) during the whole period of exposition at the climatic station.

The parameters have been determined for the trend linear function that approximates time series terms of the forecasted variable. Moreover, standard errors and Pearson's linear correlation coeff of exposition, the impact resistance of the AW coating was 50 cm (Table 9).

Table 9.
The selected estimations of the linear trend model

	AW	
Form of regression equation	$\hat{y}_t$ =-0.41t + 50.89	
Standard error of parameters of function trend	$\bar{\sigma}_a$ = 0.08	$\bar{\sigma}_b$ = 0.35
Correlation coefficient – r	-0.92	
Standard error of estimation	0.41	

The average month reduction of impact resistance for the AW coating was less than 0.5 cm. Additionally, the correlation coefficient r showed strong linear dependence of tested variable values i.e. AW coating impact resistance and time (r = -0.92).

After the determination of trend function form, predicted values for particular observation periods were calculated and standard error for this value was estimated.

The impact resistance of 50 cm was assumed in the first two months of exposition for AW coating system and used in computations. Low values of z_t parameter indicate that the model reflects the data structure very well (Table 10).

Table 10.
Predicted values calculated on the basis of the linear trend model

t	n	y_t	$\hat{y}_t$	z_t	$\bar{\sigma}_{\hat{y}_t}$
Period (October-April)	1 (t_1)	50.0	50.5	-0.5	0.28
	2 (t_2)	50.0	50.1	-0.1	0.22
	3 (t_3)	50.0	49.7	0.3	0.17
	4 (t_4)	49.7	49.2	0.5	0.16
	5 (t_5)	49.0	48.8	0.2	0.17
	6 (t_6)	48.5	48.4	0.1	0.22
	7 (t_7)	47.5	48.0	-0.5	0.28

The next stage was the formulation of a point forecast and a range forecast for the impact resistance of acrylic waterborne coating for subsequent 3 months (Table 11).

If the linear trend is maintained, the AW coating impact resistance should be equal to 46.8 cm (Fig. 4) after subsequent three months of exposition at climatic station. Assuming the confidence level of 0.95, one can estimate that the expected value of impact resistance for the coating is going to be not lower than 45.5 cm and not higher than 48.0 cm.

Table 11.
Results of forecast calculus of impact resistance for AW coating during 3 month period

n	$\mathbf{E}\left(\hat{y}_{t=n+\omega}\right)$	Confidence interval -95%	Confidence interval +95%	Ψ_{pT}
8 (t_8)	47.6	46.7	48.5	0.18
9 (t_9)	47.2	46.1	48.3	0.44
10 (t_{10})	46.8	45.5	48.0	0.52

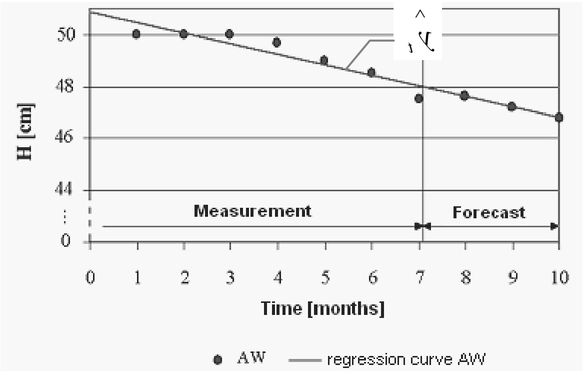

Fig. 4. Course of time series

It can be found from the analysis of the forecast mean error that the forecast precision is high (Ψ_{pT} = 0.52%). Assuming this short term forecast and establishing further maintenance of the linear trend, one can expect that the AW coating would reach its minimal impact resistance (25 cm) after 62 months of exposition at the climatic station. This means 5 years of safe operation in the machine industry.

4.4. Abrasion resistance (grindability)

The series of grindability values y_t of tested coatings in time ascending has been formulated and equalized by means of the linear trend function (Table 12).

Table 12.
Linear trend model estimations

	AW	EW
Form of regression equation	$\hat{y}_t$ =0.16t + 0.55	$\hat{y}_t$ =0.09t + 0.29
Standard error of parameters of function trend	$\bar{\sigma}_a$ =0.019 $\bar{\sigma}_b$ =0.087	$\bar{\sigma}_a$ =0.002 $\bar{\sigma}_b$ =0.010
Correlation coefficient – r	0.96	0.99
Standard error of estimation	0.10	0.01

The average month increase of grindability maintained the level of 0.16 kg/µm in the case of the AW coating and of 0.09 kg/µm – in the case of the EW coating.Pearson's correlation coefficient showed a very strong linear dependence between the grindability of epoxy waterborne coating and exposition time (r=0.99). The trend function has been determined, expected values calculated for particular periods of observation and standard error estimated for this value (Table 13).

Table 13.
Predicted values calculated on the basis of the linear trend model

t	n	y_t	$\hat{y}_t$	z_t	$\bar{\sigma}_{\hat{y}_t}$
			AW		
Period (October-April)	1 (t_1)	0.61	0.71	-0.10	0.07
	2 (t_2)	0.86	0.87	-0.01	0.05
	3 (t_3)	1.05	1.03	0.02	0.04
	4 (t_4)	1.32	1.19	0.13	0.04
	5 (t_5)	1.46	1.35	0.11	0.04
	6 (t_6)	1.48	1.51	-0.03	0.05
	7 (t_7)	1.56	1.67	-0.11	0.07
			EW		
	1 (t_1)	0.38	0.38	0.00	0.01
	2 (t_2)	0.46	0.47	-0.01	0.01
	3 (t_3)	0.58	0.56	0.02	0.00
	4 (t_4)	0.66	0.65	0.01	0.00
	5 (t_5)	0.74	0.74	0.00	0.00
	6 (t_6)	0.82	0.83	-0.01	0.01
	7 (t_7)	0.92	0.92	0.00	0.01

It can be found from the analysis of observed values in the case of AW coatings that the dynamics of grindability increase is distinctly reduced within the last two months of exposition and thus the matching between the linear model in the data structure is worse. Reminder minimal values and standard error of predicted value in the case of EW coating prove the very good matching between the model and the analyzed time series.

The next stage was the formulation of point forecast and grindability ranges for tested coatings in subsequent 3 months (Table 14).

Table 14.
Forecast calculus results of coating grindability changes within 3 months

n	$\mathbf{E}\left(\hat{y}_{t=n+\omega}\right)$	Confidence interval -95%	Confidence interval +95%	Ψ_{pT}
		AW		
8 (t_8)	1.83	1.61	2.06	0.09
9 (t_9)	2.00	1.73	2.26	0.11
10 (t_{10})	2.16	1.84	2.47	0.13
8 (t_8)	1.01	0.98	1.03	0.01
9 (t_9)	1.10	1.07	1.13	0.01
10 (t_{10})	1.19	1.15	1.22	0.02

When the linear trend has been maintained, one can expect that the grindability in the case of AW coating is 2.16 kg/µm after next three months of exposition at the climatic station and 1.19 kg/µm – in the case of EW coating (Fig. 5). Assuming the level of confidence of 0.95, one can estimate that grindability expected value after three months of exposition is not lower than 1.84 kg/µm for the AW coating and 1.15 kg/µm for the EW coating. but not higher than 2.47 kg/µm for the AW coating and 1.22 kg/µm for the epoxy coating. It is worth mentioning that the forecast precision is high, especially for the EW coating (error values of 0.02%).

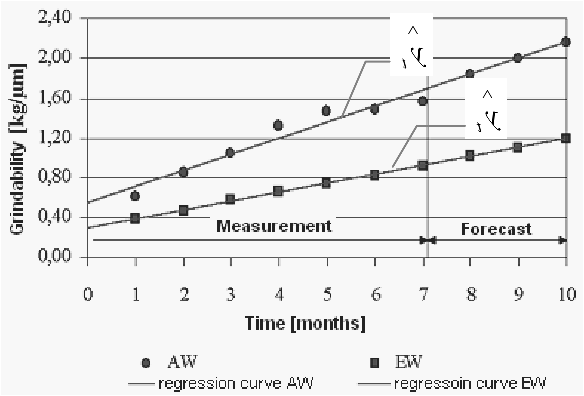

Fig. 5. Course of time series

4.5. Microscopic image

To complete the description of basic mechanical properties, several images of coating surfaces have been taken before ageing and after 180-day exposition at the corrosive station. Some of them are presented in Figs. 6-7.

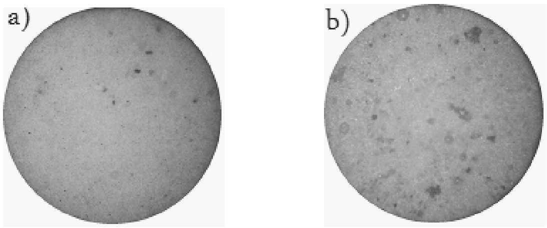

Fig. 6. AW coating surface a) before ageing; b) after exposure in the corrosion station (magnificaton 200 times)

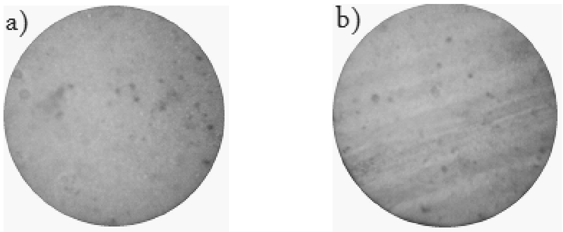

Fig. 7. EW coating surface a) before ageing; b) after exposure in the corrosion station (magnificaton 200 times)

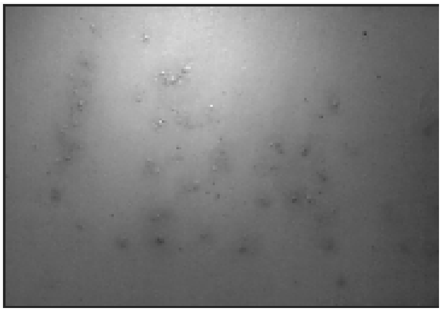

Fig. 8. Passive surface of AW coating

It can be found from the analysis of images that the most serious damage has been made to the waterborne acrylic coating. On the tested (active) side of the coating, however, the signs of corrosion have not been observed but they have been visible on the passive side (opposite to the bottom). The most probable reason is high moisture condensation from bottom evaporation and that is why numerous focuses of undersurface corrosion have been observed (Fig. 8).

5. Conclusions

The analysis of tested coating property changes in the result of exposition to natural conditions completes the knowledge of possible applications on steel machine elements and devices. The destructive agents acting on tested coatings during half-year exposition at the climatic station damaged the waterborne acrylic coating AW in the most serious way. The distinct increase of grindability of these coatings have been observed and in the case of the AW coating additional increase of scratch hardness and slight decrease of impact resistance have been found. Similar changes refer to the EW coating. The reason for such high increase of abrasion could be atmospheric fall that could rinse out some components such as pigments, filling materials or plasticizers. The additional measure for the damage process is lost of gloss on coating surfaces. The ability loss to reflect light from surfaces proves the emergence of changes in top layers. This phenomenon is additionally proved by the analysis of images of tested coating surfaces. The highest degree of degradation appears on the waterborne acrylic coating. In the result of high humidity, some additional focuses of undersurface corrosion have emerged. They eliminate this coating from applications on steel machine elements operated in natural conditions. The possibility remains only in so called dry environments e.g. in industrial rooms, storehouses, etc or in the case of application of additional protection by means of zinc coating. Moreover, the images of waterborne epoxy coatings show some slight changes which, at simultaneous high mechanical properties, proves very strong protective properties of this coating. In this context, the EW coating can be used without reservations in the machine industry, on steel machine elements and devices operated in natural conditions. The considered waterborne coatings can be successfully used to paint steel construction of different types, such as: girders, posts, rib domes, masts, door frames, gates, racks, railings, scaffoldings, platforms, caution marks, etc.

Short-term forecasts of mechanical property changes of samples exposed at the corrosion station in industrial environment that are presented in this paper do not provide full description and determination of durability for tested coatings. The presented analyses of gloss reduction and impact resistance indicate safe periods of operation of about 5 years for 50-65 μm coating thickness. The intention is to present forecast mechanisms as a method of wide application to determine durability of waterborne coatings in the machine industry. The durability is the particular property that is of the most interest for investors, users, designers and manufacturers of paint materials.

It can be predicted that these types of coatings would replace more and more solvent coatings which are harmful to the environment but widely used in the machine industry. However, because of high susceptibility to water of those ecological coatings, it is necessary to improve recipes of paint materials and carry out further research in this field to extend continuously their area of applications. This approach can lead to the total reduction of emission of organic solvents, according to the recent restrictions and regulations coming from the rules of environment protection (EC Directive 99/13) [11]. Solvent coatings can be eliminated from the use in machines and devices in the future.

The problems described in this paper indicate wide possibility for the continuation of research in the area of analyses of the influence of investigated destructive factors on mechanical properties of waterborne acrylic coatings and epoxy coatings used to protect steel backgrounds. The research could be directed towards materials based on some other waterborne resins (e.g.: polyurethane, siloxanes) or towards other aggressive agents acting on coatings, such as: sulfur dioxide, acid water solutions, alkalis, detergents, sea water. They are representative for specialized areas of machine industry (chemical industry machines, shipbuilding industry, food industry, etc.)

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