

## Study of combined packaging materials for steel products

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**Abstract.** Metal products are subject to atmospheric corrosion during transportation, long-term storage and operation. According to experts, corrosion destroys up to a third of the annual production of ferrous metals that is the reason for the annual economic losses of large metallurgical enterprises. An important area in the fight against corrosion is the search for new packaging materials containing volatile corrosion inhibitors. The urgency of the problem under investigation lies in the fact that the export of metal products is mainly effectuated by sea through areas with a humid tropical climate. The paper investigates structural, physical, deformation, strength, barrier and corrosion resistance properties of domestic packaging papers in comparison with Fislage's foreign equivalent. It studies packaging paper protection of cold-rolled steel under periodic humidity concentration. In order to increase the competitiveness of domestic packaging composite materials for metal products, it is necessary to improve their production technology, for example, by increasing the inhibitor content in packaging materials and the creping of the paper base, or by increasing the deformation-strength properties due to reinforcement.

### 1. Introduction

In the Russian Federation the annual loss of metals due to corrosion reaches 12% of the total mass of the country's metal reserves. Innovative methods of protecting metal products from corrosion during transportation and storage are the use of packaging materials containing corrosion inhibitors. Currently, some manufacturers offer combined paper-based materials containing corrosion inhibitors that can favorably compete with standard corrosion protection aids (oils, lubricants, varnishes, paints enamels, etc.) [1-6]. The issue of metal protection against atmospheric corrosion has become particularly acute due to expanded metal export volumes as metal products are often transported by open top wagons or by sea through the regions with wet tropic climate.

Up-to-date package for steel products shall fully exclude intrusion of corrosive water steams and aggressive gases to metal surface and have the required mechanical properties providing its own integrity and preservation of the packed steel products against mechanical damage during handling and transportation over long distances.

The above conditions are met by combined packaging materials with volatile corrosion inhibitors [2-6] that are made of a layer of crepe paper laminated with polyethylene and/or reinforced with polymeric threads and cloth. Reinforcement with polymeric threads contributes to better material strength. Similar packaging materials are widely used for packaging steel rolls, steel sheet packs, wire and other metal products. These materials may be used at power-driven and automated packaging units. The following de-preservation at the customer site is reduced to package removal.



In recent years, foreign combined materials were mostly available in the market. However, after Russian export sanctions have been imposed, domestic packaging papers are more widely used.

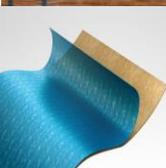
The aim of this investigation is to estimate deformation, strength and corrosion protection properties of combined packaging materials containing corrosion inhibitors.

To achieve the target goal, the following tasks were solved: investigation of deformation and strength properties of packaging papers; investigation of barrier properties of packaging papers; estimate of corrosion protection properties of packaging papers under atmospheric corrosion condition.

## 2. Materials and methods

Research targets are combined packaging materials manufactured by JSC PP Tekhnokhim (Magnitogorsk); crepe inhibited paper laminated with polyethylene foil EuroBum manufactured by Production Commercial Association “Europack-Lebedyan” (Moscow); crepe laminated inhibited paper reinforced with polypropylene grid by FISLAGE Flexibles GmbH (Germany). Samples of packaging papers and their properties are listed in table 1.

**Table 1.** Survey objects.

Sample designation	General view	Manufacturer	Packaging material characteristics
BLIK		JSC PP Tekhnokhim	Crepe packaging paper with polyethylene coating
BLIK-1		JSC PP Tekhnokhim	Crepe inhibited laminated paper
BLIK-3		JSC PP Tekhnokhim	Crepe inhibited laminated paper BLIK reinforced with polypropylene threads
EuroBoom		PLC Production Commercial Association Evropak-Lebedyan	Crepe inhibited paper laminated with polyethylene foil
Fislage		FISLAGE Flexibles GmbH	Crepe inhibited laminated paper reinforced with polypropylene grid

Deformation and strength properties of materials were tested at digitally controlled IP 5158-0,5 test bench as per GOST 30436-96 (ISO 1924-2-85). Based on test results, the strength and tensile elongation were calculated.

The weight of 1 m<sup>2</sup> paper was computed according to GOST 13199-88.

Inhibitor residuals in anti-rust paper were determined according to GOST 16295-93.

Vapor permeability of combined materials was calculated as per GOST 9.507-88. The test issue is in determination of the weight of moisture vapor passing through 1 m<sup>2</sup> combined material for 24 h at 20 °C and (95±5) % relative humidity.

Water adsorbency at one-side wetting was determined according to GOST 12605-97 (Cobb's method). The method includes determination of the water weight (g) absorbed by paper surface at wetting one side of the sample for 60 sec.

Samples of 08-Yu cold rolled products were used for study of corrosion protection properties.

Protective properties of inhibitor paper sheets were tested with the gravimetric method in the heat and moisture chamber according to GOST 9.054-75. Corrosion damage was visually checked. The index and rate of uniform corrosion were calculated based on the test results [7-8].

### 3. Investigation results and their discussion

Results of calculation of structural and physical properties of packaging papers are provided in table 2.

**Table 2.** Structural and physical properties of packaging papers.

Specimen designation	Thickness (mm)	1 m <sup>2</sup> paper weight (g/m <sup>2</sup> )	Inhibitor weight (g/m <sup>2</sup> )	Inhibitor content
BLIK	0.27	122	-	without an inhibitor
BLIK 1	0.21	112	12	Sodium nitrite and urotropin (1:1)
BLIK 3	0.21	117	9	
EuroBoom	0.54	166	5.4	Contains nitrites <sup>a</sup>
Fislage	0.35	157	9.5	

<sup>a</sup>Note: calculated according to GOST 16295-93

The weight of 1 m<sup>2</sup> packaging papers correlates to their thickness. Content of volatile inhibitor in 1 m<sup>2</sup> papers under study is nearly the same and amounts 9-12 g/m<sup>2</sup>, which is sufficient for metal corrosion protection. The inhibitor content in the EuroBoom paper is low– 5.4 g/m<sup>2</sup>.

Packaging papers of JSC PP Technokhim contain UNII volatile inhibitor specified in the reference documents for these products. Inhibitor content of the Fislage's and EuroBoom papers is confidential, but identification tests in water extracts based on packaging papers detected nitrite ions [8].

Deformation and strength properties of packaging papers are provided in table 3.

**Table 3.** Deformation and strength properties of packaging papers.

Specimen designation	Breaking force (N)	Relative elongation (%)	Tensile strength (kN/m)
BLIK	40	38	2.7
BLIK 1	63	5	4.2
BLIK 3	86	22	5.7
EuroBoom	55	55	3.7
Fislage	88	36	5.9

According to the strength properties, domestic packaging paper is inferior to foreign analogues, except for paper laminated with polypropylene fabric: the tensile strength of EuroBoom packaging paper is 1.6 times lower. Due to the inadequate strength properties of EuroBoom packaging paper, problems can arise in the mechanized packing of steel rolls.

Investigation of barrier properties of packaging materials is essential for metal protection against atmospheric corrosion, as the package should fully prevent water vapor access to metal surface

because condensing moisture is a corrosion source and enhancer. Results of vapor permeability computing at 20 °C are shown in table 4.

**Table 4.** Barrier properties of combined packaging materials.

Specimen designation	Thickness (mm)	Vapor permeability ( $\text{g}/\text{m}^2 \cdot \text{day}$ )	Adsorbency ( $\text{g}/\text{m}^2$ )
BLIK	0.27	64	60
BLIK 1	0.21	76	64
BLIK 3	0.21	66	61
EuroBoom	0.54	42	58
Fislage	0.35	81	95

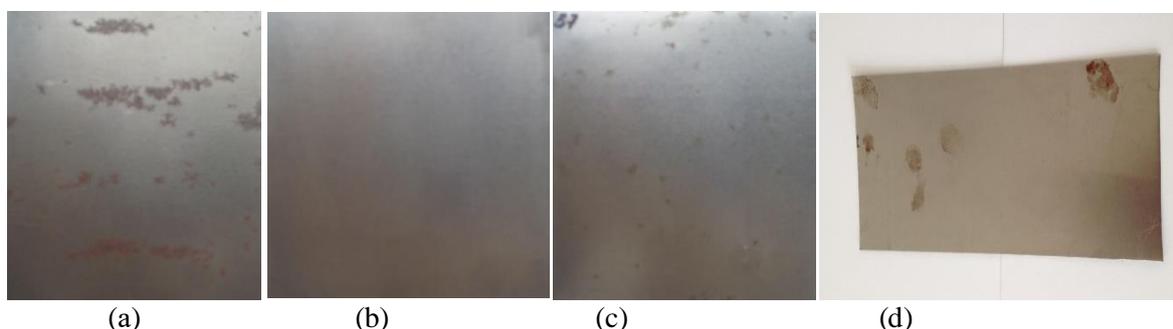
Relatively low vapor permeability is specific for EuroBoom specimen as this packaging material has the greatest thickness. A high adsorbency of Fislage's packaging paper is conditioned by the greater creeping ratio.

Metal plates packed in corrosion protection papers were exposed to 95 % relative humidity and at 40 °C for 7 h and for 17 h at room temperature and moisture condensation. Test total duration was 20 cycles/480 h. The area damaged by corrosion was determined based on samples. The mass of corrosion products and the rate of uniform (general) corrosion were gravimetrically determined [6-7]. The test results are shown in table 5.

**Table 5.** Results of corrosion protection tests at cold-rolled steel samples under conditions of periodic humidity condensation.

Specimen designation	Corrosion product weight (g)	Corrosion area ( $\text{cm}^2$ )	Corrosion index ( $\text{g}/\text{m}^2$ )	Corrosion rate ( $\text{g}/\text{m}^2 \cdot \text{h}$ )
BLIK	0.003	1.60	0.24	$5.0 \cdot 10^{-4}$
BLIK 1	0	0	0	0
BLIK 3	0.0002	0.02	0.02	$3.3 \cdot 10^{-5}$
EuroBoom	0.02	1.38	0.96	$3.9 \cdot 10^{-3}$
Fislage	0.002	0.04	0.17	$3.5 \cdot 10^{-4}$

Figure 1 shows appearance of samples after corrosion tests under conditions of periodic humidity concentration.



**Figure 1.** Appearance of samples after corrosion tests under conditions of periodic humidity concentration: (a) – BLIK; (b) – BLIK 1; (c) – Fislage; (d) – EuroBoom.

Conducted tests confirm corrosion protection efficiency of combined packaging materials of JSC PP TechnoKhim. All studied materials of JSC PP TechnoKhim have better protective properties than

those of foreign products. The EuroBoom paper does not have any protective action. It has poorer corrosion protection properties than those of the Fislage's paper: the corrosion index is by 5.6 times higher, which can be explained by a lower content of corrosion inhibitor.

#### 4. Conclusion

The issue of selection of packaging materials for metal products is especially relevant under condition of import substitution. Comparison of domestic packaging materials manufactured by JSC PP TechnoKhim and EuroBoom paper with the foreign counterpart has proven that products offered by JSC PP TechnoKhim provide the best protection against atmospheric corrosion than that of previously used foreign analogues. These combined materials may be recommended for packaging cold-rolled steels.

In conclusion it should be noted that to improve the competitiveness of domestic composite packaging materials for metal products it is necessary to improve their production technology. This can be achieved by increasing the content of the inhibitor in packaging materials, by increasing the creping of the paper base, by increasing the deformation-strength properties due to reinforcement, and by developing new packaging materials [5].

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