Strength and optical properties of papers subjected to artificial light ageing

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The paper presents strength and optical properties of selected paper printing bases put to operational use such as artificial light ageing. The process influences significantly the quality of printing products.

The aim of the experiments performed was to reveal the changes occurring in paper during different stages of its operational use. The results obtained enabled to compare the strength and optical properties of the tested bases exposed to light with those found for the paper referred to as "long-lived paper".

Keywords and phrases: artificial light ageing, light fastness, colour coordinates, paper printing bases, long-lived paper.

Introduction

The changes due to paper ageing are not noticeable as only after a long period of time. Tests performed under normal conditions could last 20 to 50 years or even more. Realization of experiments carried out for such a long time is practically impossible. For this reason the paper ageing under laboratory conditions, called "artificial ageing", was invented. The paper is treated with some specific agents in specially designed devices. The most important factors playing fundamental role in paper destruction are: increased temperature and relative humidity, as well as light radiation. The knowledge of interaction of these elements with paper has allowed to work out a procedure of its artificial ageing in specially designed climatic chambers and devices intended for investigation of the effect of light radiation on paper bases (Fig. 1). Ageing of materials under different types of destructive factors is called artificial complex ageing. There exist possibilities to compare the results obtained under laboratory conditions with those in normal conditions. Such devices are very useful as they enable to foresee the changes occurring inside the paper in normal conditions. For Central Europe 26 days of artificial light ageing in Suntest CPS+ device is almost equivalent to 1 year of ageing under normal conditions of a sample placed indoor, while 31 days of artificial light ageing in the aforementioned device is almost equal to 1 year of ageing in normal conditions of a sample placed outdoor. It is worth to mention that Central Europe is characterized by average illumination intensity on a world scale [10].

The direction of cellulose fibers is a very important matter in paper strength testing. Differences in mechanical and physical properties observed in two paper directions are due to its anisotropic character which is a consequence of web forming and dewatering processes. These anisotropic features are noticeable in parallel and orthogonal directions to paper machine screen running. The paper has better tensile properties, better folding endurance and is more rigid in the parallel direction, whereas it is less tensile, less tear resistant and more susceptible to linear strain in the orthogonal direction. The anisotropic effect is very undesirable for most of paper bases. The anisotropic value of paper should be close to one.

The tensile strength is one of the most important mechanical properties of paper. This property, expressed in Newtons, affects other mechanical properties of paper such as: burst resistance, double folding and tear resistance. The tensile strength depends mainly on the amount and strength of bindings between the fibres and, to a lesser extent, on the fibres' length. The tensile loading is always larger in parallel than in orthogonal paper direction by about 50–100% [9]. The tensile properties of paper are determined by ISO 1924-2 [5].

Another equally important mechanical property of paper is its tear resistance. This parameter determines the force necessary for tearing the incised paper sample. The tear resistance is always higher in orthogonal paper direction. It depends mostly on the fibres' length. The tear resistance is tested in Elmendorf device [6].

Experimental

Materials and laboratory setup

Tests were carried out with three different bases, namely: two uncoated white paper bases and one gloss coated paper. One of the papers tested (uncoated one) is generally known as a long-lived paper. It conforms to ISO 11108 [1] and ISO 14416 [4] standards in which the requirements concerning documents' durability are defined. This paper is characterized by high degree of sizing, high dimension stability, high brightness and alkaline reaction. The papers tested were denoted in this article as:
1 — uncoated white paper,
2 — uncoated white long-lived paper,
3 — coated gloss paper.

The aim of this research was to compare the strength and optical properties of selected paper printing bases exposed to operational use such as artificial light ageing in Suntest CPS+ device (Fig. 1).

Fig. 1. Suntest CPS+ device.

Following the ageing procedure optical and mechanical properties of the papers tested were measured. For this reason we used:
— a Ziwck Roell tensile testing machine (Fig. 2),
— an Erichsen Picogloss 503 glossmeter, and
— a Gretag Macbeth spectrophotometer.

Fig. 2. Ziwck Roell Tensile testing machine.

Artificial light ageing tests were carried out according to ISO standards [2, 3, 7, 8] in a Suntest CPS+ device. The following measuring conditions were applied:
— intensity of illumination — 550 W/m^2,
— black standard temperature — 50°C,
— daylight filter (lower limit — 290 nanometer).

The filter used allowed to simulate the solar radiation present outwards. Three different paper bases were tested to light exposure for 48 hours, which is almost equal to 23 days of ageing under natural outdoor conditions and about 28 days of ageing under natural conditions prevailing indoors. The dimensions of the examined samples were 28 × 20 cm. After every one-hour exposition to light in Suntest CPS+ device the papers were evaluated visually, then the optical properties were measured. The properties such as gloss at measuring angles of 20, 60 and 85°, colour coordinates CIELAB as well as colour attributes $CIELCh_{ab}$ were measured under the following conditions:
— absolut,
— illuminant D50,
— 2° colorimetric observer,
— measuring geometry 0°/45°,
— density standard DIN NB.

The papers exposed to light were then subjected to destructive testing in order to determine their strength properties such as tensile strength. The tests were carried out according to ISO 1924-2 [5] standard under the following conditions:
— temperature — 24°C,
— relative humidity — 25%,
— tension speed — 20 mm/min,
— force value — 500 N,
— sample dimensions — 15 mm × 101 mm.

The tests were carried out for both parallel and orthogonal fibre direction.

Results and discussion

The results obtained have shown that the surface of the white uncoated long-lived paper denoted in this article as number 2 was unexpectedly much more destructed than that of the uncoated white paper base denoted as number 1.

Visual evaluation showed that the discoloration of papers exposed to light was noticeable as early as after one hour of exposition. The degree of paper discoloration became more and more significant with increasing time of exposition. Unexpectedly, the highest ease of discoloration was observed in papers with increased resistance to degradation. None of the papers tested underwent surface deformation due to light exposition.

Optical properties of the paper printing bases tested, such as:
— gloss,
— CIELAB colour coordinates,
— CIELCh$_{ab}$ colour attributes: saturation — C_{ab}^* and shade of hue — h_{ab}^o,
— brightness (CIE, R457),
were measured.

Gloss measurements of surfaces subjected to artificial light ageing process were performed after every one hour of exposure in the Suntest CPS+ device. Analysis of the results showed that artificial light ageing does not affect significantly the gloss of tested substrates. This applies to both uncoated and gloss coated papers.

Brightness measurements were carried out during different stages of artificial light ageing. Both CIE and R457 brightness was tested. The results obtained have been shown in Fig. 3. The highest changes in brightness were observed in papers 2 and 3, the smallest in paper 1. After 48 hours of the light exposition the brightness decrease for papers 2 and 3 was about 39 and 37 units, respectively. The uncoated white paper base (number 1) exhibited smaller changes in brightness due to artificial light ageing. It was about 27 units after 48-hour exposition to light. Similar relationships were observed for the brightness R 457.

The measurements of CIELAB colour coordinates as well as of CIELCh$_{ab}$ colour attributes have shown that changes in CIELAB chromatic colour coordinates a^* and b^* caused by artificial light ageing influence strongly the

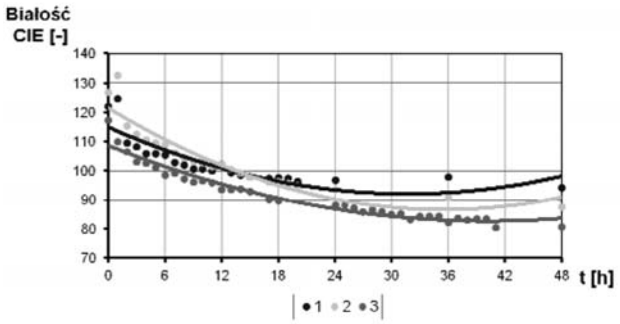


Fig. 3. Changes in CIE brightness due to artificial light ageing. 1 — uncoated white paper, 2 — uncoated white long-lived paper, 3 — coated gloss paper.

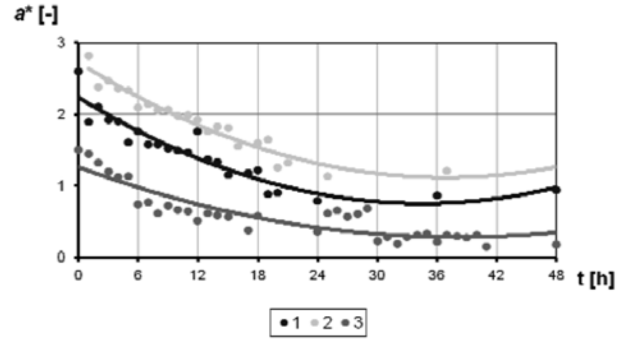


Fig. 4. Changes of CIELAB a* chromatic colour coordinate.

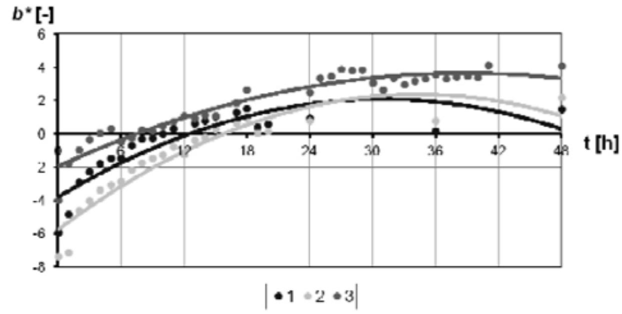


Fig. 5. Changes of CIELAB b* chromatic colour coordinate.

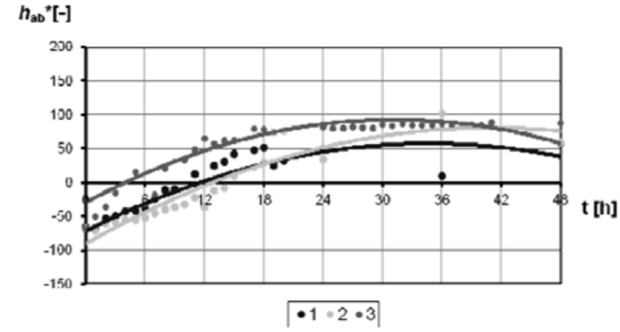
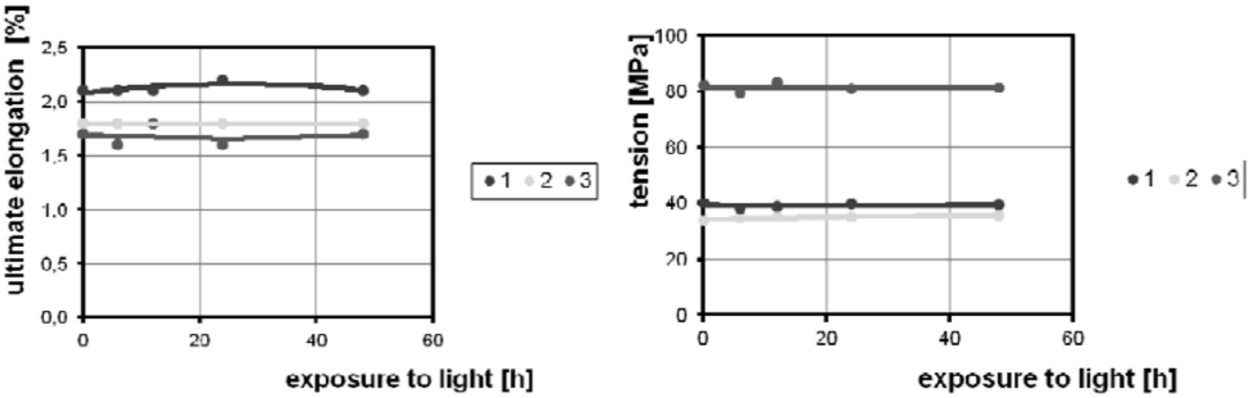


Fig. 6. Changes of CIELCh$_{ab}$ h_{ab}^o shade of colour attribute.



a) b)

Fig. 7. Ultimate elongation a) and tension b) during tension testing of papers exposed to light. 1 — uncoated white paper, 2 — uncoated 'long-lived' white paper, 3 — coated gloss paper. Fibre — parallel direction.

colour shift to yellowish colours. The most significant were the changes in colour coordinate b^*, then in the colour coordinate a^*. Significant changes were observed also in the h_{ab}° shade of colour change (Fig. 6). The biggest changes in a^* parameter were observed for the paper 1 — uncoated white whereas the smallest for paper 3 — gloss coated one. For paper 1 it was about 1.7, for paper 2 — 1.6 and for paper 3 — about 1.3 units.

The changes in b^* parameter were the biggest for paper 2 — named as 'long-lived paper' — about 9.5 units and the smallest for paper 1 — uncoated white paper — about 7.5 units. The changes in chromatic colour coordinates a^* and b^* are shown in Fig. 4 and 5.

The ageing of samples exposed to artificial light was also examined in terms of changes in mechanical properties such as tensile strength.

The tests performed has shown that artificial light ageing for 48 hours does not influence the strength properties of papers, such as a tensile strength and ultimate elongation. The obtained results are shown in Fig. 7a and 7b.

Conclusions

The obtained results has enabled to conclude that paper that meets the conditions of 'long-living' paper in accordance with ISO 11108 [1] and ISO 14416 [4] is characterized by a worse resistance to operational use process such as artificial light ageing during 48 hours than other papers tested in this work.

The artificial light ageing strongly influences the optical properties of paper such as brightness, colour coordinates and colour attributes, but has no impact on the gloss value or strength properties of the paper bases tested.

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