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Investigation of physical and mechanical properties changes of papers during thermal ageing

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The papers and boards are the main used materials for printing industry. Therefore, it is very important to know their characteristics and peculiarities and to know in advance, how their properties would change all over the time it is used and stored. Over the time all papers and boards change their physical, mechanical and chemical properties – called papers ageing processes. The ageing is an irreversible process. As much slower the process of ageing, as longer life of paper is expected. The papers examined in this research, are chosen for their wide use and popularity in the world printing industry. The aim of the present study is to investigate the influence of artificial thermal ageing at 105^{o}C on the basic physical, mechanical and optical properties of all types of investigated papers. Various structural and dimensional properties, as well as physical, mechanical and optical properties were determined before, during and at the end of the artificial thermal ageing process. From the results obtained it is clear that the different fibrous composition and the storage conditions have a great influence on the ageing of the paper. All investigated parameters take changes in specific and different ways, but all of them decreasing in the ageing process.

Keywords: thermal ageing**,** physical-mechanical and optical properties of papers, papers and boards

INTRODUCTION

Each paper changes its physical, mechanical and chemical properties over time - paper ageing - and the process is irreversible. With long-time natural ageing, the fibers in the paper lose their elasticity [1, 2]. Paper ageing is a complex process whose nature is still poorly understood as it is influenced by many factors [2]. Most important is the action of light and heat. There are two types of ageing of fibrous materials - thermal and photo ageing. Thermal ageing is in most cases due to oxidation processes under the action of oxygen from air and hydrolysis under the action of humidity. The durability of the paper is its ability to retain certain physico-mechanical, optical and chemical properties unchanged over time [3, 4]. The most commonly used conditions for artificial thermal ageing are:

• temperature of 105 ± 2°C in a dry air circulation chamber (ISO 5630-1: 1991) and temperature of 80°C at 65% relative humidity (ISO 5630-3: 1996).

For these parameters, it is assumed that treatment over 3, 6, 12 or 24 days corresponds, respectively, to 25, 50, 100 or 200 years of natural ageing of the paper. Under the direct influence of light (solar or artificial), new papers quickly turn yellow and become fragile [5, 6].

EXPERIMENTAL

The international standard ISO 12647-2: 2004 lists the main types of paper for sheet and roll printing used most widely in practice [5-9]. The following paper types were used for the experiment: LWC (Light Weight Coated) and NP (Newspaper). The papers examined in this research were chosen for their wide use and popularity in the world printing industry.

Structural-dimensional properties of the studied papers determined:

- Humidity (EN 20287: 1996);
- Type of fibrous material (microscopic analysis) (EN 8658-71);
- Weight (g/m^2) (EN ISO 536: 1998);
- Thickness and density (EN ISO 534: 2006).

Microscopic analysis of the fiber structure of the examined papers was made.

Basic physical-mechanical properties determined:

- Tensile index (EN ISO 1924-2: 2000);
- Tear index (EN ISO 21974: 2001);
- Burst index (EN ISO 2758: 2005).

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Optical properties determined:

- Brightness (R457);
- Yellowness (ISO 2470:2007).

A spectrophotometer (SpectroEye) was used under measurement conditions: light source D65, observer angle 10^o. The change in artificial ageing was monitored before and after 6, 12, 24, 36, 48 hours of ageing.

RESULTS AND DISCUSSION

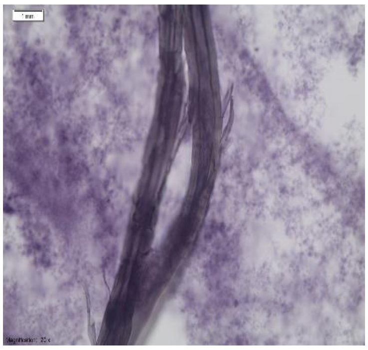
Determination of structural-dimensional properties of the studied papers

The following analyses were made on both types of paper as shown in Table 1.

Table 1. Structural-dimensional properties of the studied papers

Type of paper	Weight, (g/m^2)	Thickness, (μm)	Density, (kg/m^3)	Humidity, (%)
LWC	89	1.1	80	4.37
NP	45	1	45	7.73

Picture 1. LWC



Picture 2. NP

Microscopic analysis of the fiber structure of the examined papers

The microscopic analysis was performed on an apparatus OLYMPUS BX 53. Different fiber materials were used in the production of many types of paper in a certain proportion. The microscopic pictures show the fiber composition of the papers examined. Picture 1 shows that the LWC paper contains hardwood and softwood pulps. Picture 2 (NP) shows that the newsprint is made up of a considerable groundwood pulp. Non-uniform fibers characteristic of the high-yield fibrous materials are observed. These tears are most likely caused by grinding, as well as by subsequent chemical treatment of the wood during boiling. Characteristic vessels with open edges that have extensions characteristic of deciduous wood are observed. From the pictures, the main types of fibers used in the structure of the papers under study are clearly visible.

Investigation of the basic physical and mechanical properties of the two types of papers

Figures (1-3) show the changes in the values of the basic physical-mechanical parameters of the studied papers. They determine the basic and important properties for all types of papers and cardboards.

The formation of the physical-mechanical properties of paper is influenced by a number of factors that affect the strength of the paper; they ultimately exert their effect through three main factors, and it can be said that the strength depends primarily on them. These are:

- The bonding forces between the fibers and the surface on which they act;
- The strength, elasticity and dimensions of the fibers themselves;
- Laying the fibers in the paper sheet.

Figure 1 shows the tensile index values for both types of paper and the changes that occur in the process of artificial thermal ageing at 105°C.

The tensile index depends primarily on the bonding forces between the fibers and less on the length and strength of the fibers themselves. Figure 1 shows that the largest changes in the tensile index are observed with newsprint (12.92), which is due to the fiber composition of the test paper. The changes for LWC are smaller (9.39). This indicator is most influenced by the bonding forces between the fibers and less by the length and strength of the fibers themselves. Figure 2 shows the variations in the burst index values for the paper being tested. This indicator is a complex function of the tensile index and the elongation of the paper before it tends to grow as they increase. This indicator depends on both the length of the fibers and the bonding forces between them. The biggest changes occur with the LWC, but the changes in the other paper are identical. The tendency of the studied papers is: faster changes during the first hours of the artificial thermal ageing to about 6 – 12 h and smoother decrease with the process progressing up to 24 h. Figure 3 shows the values of the test papers for the tear index. This is one of the most important properties of paper that characterizes the dynamic strength. This indicator can be used to judge the stretchability of the paper. The tear index is determined by the structure of the paper (mass, density, fiber orientation), as well as by the length and strength of the fibers, and depends only to a minimum on the bonding forces between them. The tendency to decrease this indicator is identical for all the papers examined. The fastest is the reduction again at the beginning of the ageing process to about 12 h. The largest changes (Fig. 3) in this indicator were observed in newsprint (5) and in LWC (around 4).

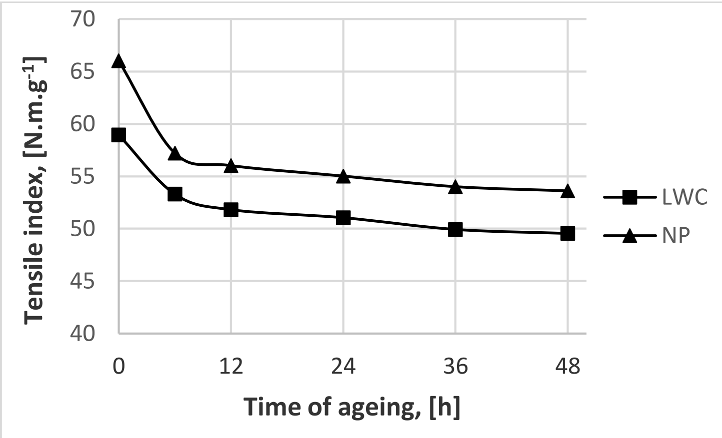


Fig. 1. Change of the tensile index of the test papers before and after artificial ageing at 105°C

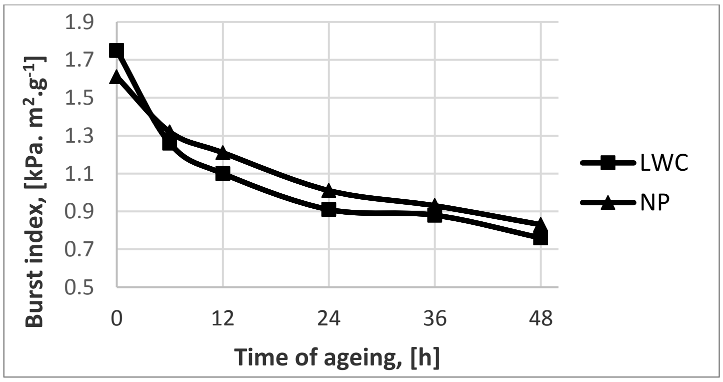


Fig. 2. Change of the burst index of the test papers before and after artificial ageing at 105°C.

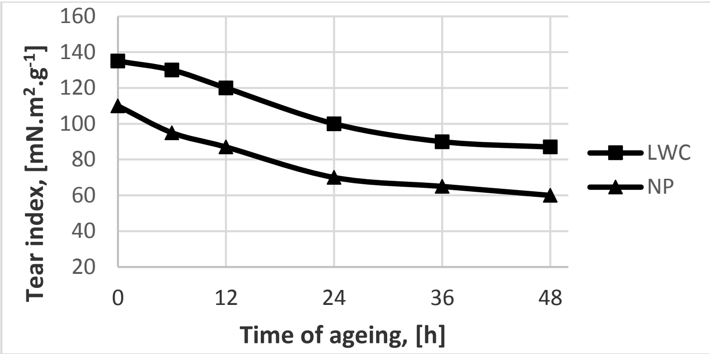


Fig. 3. Change of the tear index of the test papers before and after artificial ageing at 105ºC.

Investigation of the optical properties of the papers

The optical properties of the paper depend on the contrast of the image, the accuracy of color rendering in multicolor, the quality and appearance of the print as a whole. Some of the most important optical properties are: those related to the reflection of light – brightness, yellowness, gloss and matte. Figure 4 shows the values of the brightness change over time in the process of artificial thermal ageing at 105°C. For the first 6 hours and anywhere up to about 12 h the decrease in brightness (Fig. 4) is most dramatic, after which it becomes smoother. At least the brightness decreased with newsprint, but it had a lower initial brightness (58.88%). Figure 5 shows the changes in the degree of yellowing in the process of artificial ageing. Yellowing of the paper is a pretty important indicator for writing and printing papers. The reason for its increase is the influence of light, increase of temperature and humidity of the environment, harmful gases in the atmosphere (mainly SO_2), the type of fibrous materials used and the ways of their production. Figure 5 shows that the largest changes are the yellowness values for LWC paper (24.15) and smaller for NP due to the fiber composition. Both papers are characterized by the fastest change up to 6 – 12 h from the start of the ageing process and the subsequent tendency to gradually decrease by the end of the studied ageing period. It is seen that in the course of ageing, with the passage of time, the brightness decreases and the yellowness increases with the studied papers.

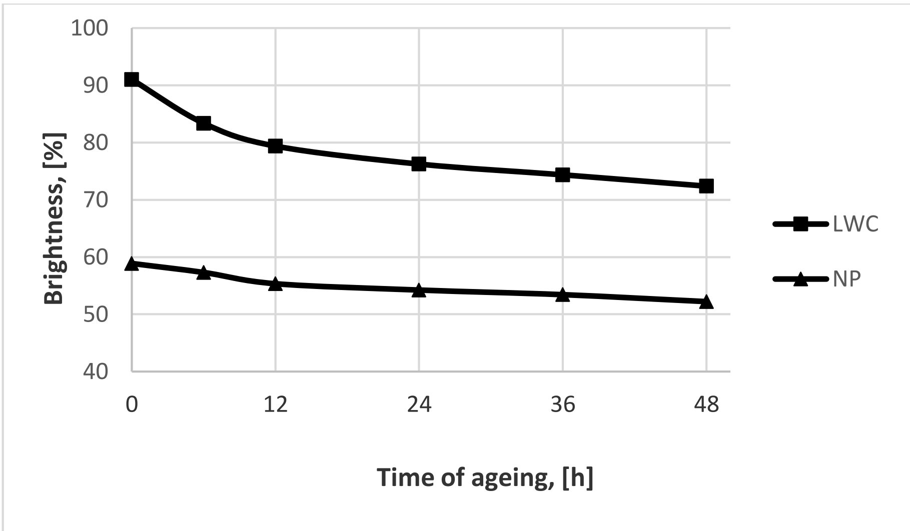


Fig. 4. Change in the brightness of the test papers in the process of artificial ageing at 105ºC.

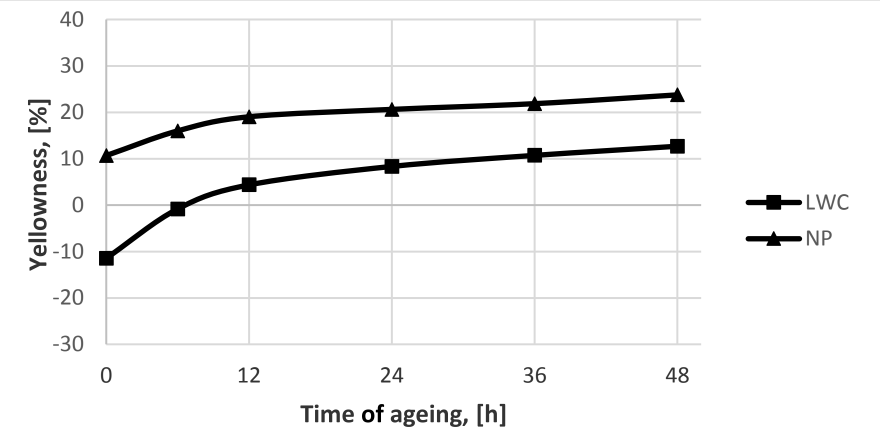


Fig. 5. Changes in the yellowness of the test papers in the process of artificial ageing at 105°C.

CONCLUSIONS

The largest changes in the tensile index are observed for newsprint (12.92), which is due to the fiber composition of the test paper. The changes for LWC are smaller (9.39). The tear index decreases most rapidly at the beginning of the ageing process to about 12 h. Major changes in this indicator were observed in newsprint (5) and smaller changes in LWC (around 4). The biggest changes in the burst index occur at the LWC, but the changes for the other paper are identical. The trend in the papers studied is: faster changes in the first hours of artificial ageing up to 6 – 12 h and subsequent gradual decrease with the progress of the process up to 24 h. It is seen that in the course of ageing, with the passage of time, the brightness rate decreases and the yellowness rate increases with the studied papers. The brightness decreased with newsprint, but it had a lower initial brightness (58.88%).

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