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CHROMATIC CHARACTERISTICS OF THE RECYCLED FIBERS

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Abstract: *In the field of sustainable design an important place occupies life cycle of printed products. One of the possibilities to increase the quality of the environment in this area arises from the selection of paper in the fiber type context, expenditures of water and energy and ink in relation to the share of renewable raw materials. In this paper the research results of chromatic characteristics of the fibers obtained by recycling prints made on different types of paper and with conventional and environmentally more favorable inks are presented. Influence of the composition of graphic materials and the dynamics of aging prints, which are processed by deinking flotation are discussed. The research results are scientific contribution in the field of deinking mechanism of aged prints and influence of graphic materials on the chromatic characteristics of the recycled fibers. Results are applicable in the field of sustainable product design and formulation of new materials.*

Key words: *offset prints, ageing, recycling, chromatic characteristics*



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1. Introduction

One of the levels of sustainability in design is the selection of resources arising from the recycling issues, eliminating toxic substances, biodegradability and renewable energy. Design for the recycling process includes the possibility of recycling materials to the technological and economic feasibility of products (Vezzoli & Manzini, 2008).

At the time of disposal of products, there are several options for used products. Thus, in some cases it is possible to restore the functionality of the product or its parts, and in some it is possible to compensate components of materials and energy of the used product. In the case of recovery of materials and energy, recycled materials are used instead of primary ones or in an open recycling loop they are used in the production which is different from the original production (McDonough & Braungart, 2002).

Introducing the life cycle of products and functional unit, there is a design of products with less effect on the environment, which is able to cope with the complexity of the problems in the context of product characteristics and environmental quality. Designing for the environment implies a new approach to designing products that takes into account the entire life cycle of products from design to all other processes that need to monitor the production of materials, its products, its distribution and use, and finally disposal as a unified whole (Brezet et al., 2001).

In recent time environmental requirements that relate to ecodesign of products consists of structured discipline that has arranged and defined theory, clear design guidelines, methods and tools (Manzini et al., 2004). Before designing the product the priorities of the strategy should be determined, so when the life cycle requires the product durability and its repeated use, it is more efficient to apply the strategy of optimization of the life cycle of products and extended durability of materials.

From the perspective of sustainability environmental items are of primary importance, but also a solution to reduce environmental impacts should be economically feasible and social and socially attractive (Brown, 2009). Used strategies must satisfy the entire set of requirements. For successful engagement of strategy of the environment it is necessary to know the category of the product.

During the phase of creation of paper graphic products ecological factors arise from the types of fibers used in the production of paper, water use and energy for its production. Design can reduce the negative impact on environment in the field of fibers: use post-consumer recycled fiber, sustainably harvested virgin fiber and tree-free alternative fibers (Dougherty, 2008).

Research presented in this work is content related to the area of post-consumer recycled paper and its disposal. In general, theory, mechanism and factors of recycling waste paper have been researched a lot. Interaction between cellulose and inks, which can be described by physical interaction (mechanical connection) and adhesive interaction (hydrogen and van der Waals bonding), which is very important from the aspect of mutual separation in the process of deinking is studied (Forsström, 2004). Factors of the process, such as: hydrophilic degree of ink particles, size and

shape of ink particles, the size of bubbles and foam structure, the type of gas and speed of flowing, the flow hydrodynamics in the cell and chemistry collectors were covered by investigations (Horak & James, 2001; Theander & Pugh, 2001).

The impact of printing techniques and graphic materials is recognizable by specific characteristics, efficiency of the procedure and by the characteristics of recycled fibers (Renner, 2000). In recent years a lot of researches aimed at improving the efficiency of deinking of flexography inks based on the water, considering the size of particles (0.2 -1.0 μm), which is too small for successful deinking flotation.

Bolanca I. and coauthor were investigating the impact of the conditions in the digital printing based on electrophotography with solid and liquid toner, model of the printing machine in particular printing technique and the composition of the substrate on the efficiency of deinking and optical characteristics of the recycled fibers (Bolanca & Bolanca, 2005).

Aging of prints can affect the mechanism of deinking flotation process. In general processes of aging prints, that is papers, can be triggered by a series of factors, and in dependence on it hydrolytic degradation treatment of cellulose molecules, oxidation of cellulose with oxygen from the air and/or degradation caused by light can be experienced. According to the investigations degradation of cellulose can be observed as oxidative and hydrolytic mechanism where the reactions are auto catalytically accelerated by active oxygen and protons (Strlic & Kolar, 2005).

In the field of researching efficiency of recycling of natural and accelerated aged prints reduction in the deinked pulp brightness change in other recycled paper properties, and change in process water after recycling waste paper aging exposed during the summer months, defined as a summer effect were studied (Haynes, 1998). It is conclusion that the summer effect is due then ageing or thermal drying of printing inks. This drying will lead to fragmentation increased ink (more to remove ink) and ink attachment (ink can not be separated from the fiber chemical or flotation mechanism).

In this paper research results of chromatic characteristics of the recycled fibers in dependence on the dynamics of aging prints that are submitted to deinking flotation are presented. The influence of printing substrate types is discussed. The influence of conventional ink, but also those with a higher share of renewable raw material is observed. The results of scientific research are contributions in the field of mechanism of deinking aged prints, and are applicable in the field of sustainable design of graphic products. Observed through the life cycle of graphic products application is possible in the phase of the product design (in the context of the application of recycled fibers for the production of fine printing papers) as well as in the design for recycling (disposal of used prints).

2. Experimental

Heidelberg printing machine was used for printing. The printing form contained different printing elements: standard CMYK wedge, standard ISO illustration for visual control, textual positive and negative microelements and standard wedge for creation of ICC profiles and 3D gamut.

Printing was done on fine art matt and glossy paper with different weight and uncoated offset paper. Conventional offset ink and ink with a larger share of renewable raw materials was used for printing.

For accelerated ageing substrate and print the climatic chamber was used, under the following conditions: temperature 80°C, relative humidity 65% and ageing time of 10, 20 and 30 days without the radiation influence.

In the phase of sample soaking, deinking chemicals (1% hydrogen peroxide, 0, 4 % surfactant, 0, 2% DTPA, 1% sodium hydroxide and 1% sodium silicate) were added. The consistency is 10% in regard to the dry substance.

A good mixing action was achieved. The disintegration stage was continued for 45 minutes. Suspension was diluted to 0, 6 % pulp consistency. An optimum level of hardness was maintained in the flotation cell from 200 ppm CaCO₃. The flotation time was eight minutes.

The handsheets were made using a laboratory sheet former, according to standard method T 205.

For assessing the effects of ageing and the evaluation of the quality of prints spectrophotometric CIE XYZ size for each field are obtained. With computer support is derived conversion CIEXYZ in CIE L*a*b*, so that 3D uniformly color space of the samples are constructed. Calculated volume of the gamut in Color Cubic Units is expressed.

For measurement X-Rite DTP-41 spectrophotometer with assistance of Monaco profiler platinum application was used.

Except that the spectrophotometer Datacolor Elrepho 450 for measurements of colorimetric characteristics of handsheets made from fibers obtained in different phases of recycling process was used.

3. Results and discussion

The result of spectrophotometric measuring is the spectral information about color obtained by measuring power at each wave length, which by using the appropriate method can be converted to tristimulus information. Tristimulus information is a description of the phenomenon, or color, how it looks under certain conditions, shown in the form of tristimulus function.

Gamut represents the overall amount of information about color, including the tone, saturation and lightness, which can be reproduced on a given medium. So as research results are given two-dimensional and three-dimensional views of the influence of accelerated aging on the gamut prints.

Figure 1 show results for non aged and accelerated aged print, made with the model ink with a larger portion of renewable raw materials.

With accelerated aging of print intensity in yellow area is substantially reduced. Also inking intensity is less from the blue-green to over the whole blue area. In the red area non aged print has somewhat smaller gamut.

Both prints, aged and non aged, match the intensities in the areas of magenta, orange and green.

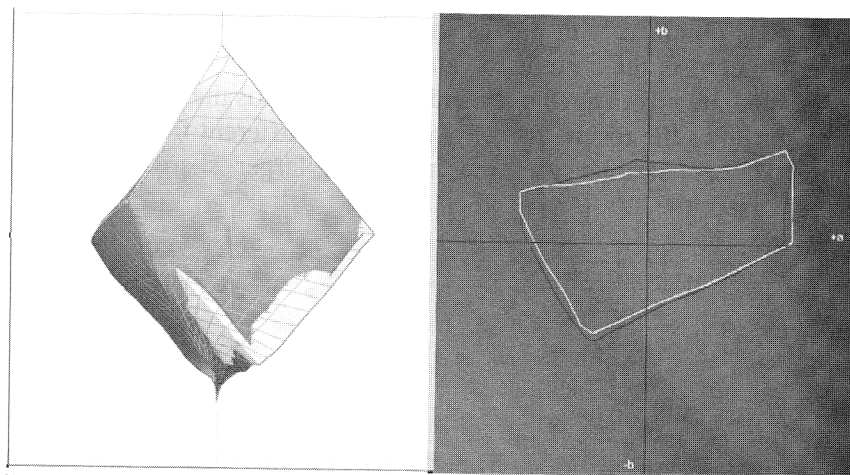


Fig. 1. Gamut of non-aged and aged prints with model ink

On the figures 2-8 the influence of the dynamics of aging prints on chromatic properties of handsheets made of fibres after prints disintegration and after flotation of aged prints is shown.

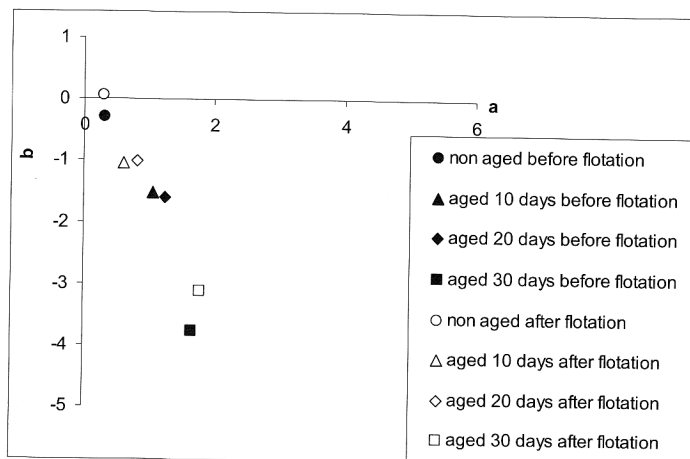


Fig. 2. Chromatic values a^* and b^* for a handsheet made from the fibres before and after flotation, depending on the dynamics of aging (print: uncoated paper, conventional ink)

Results of chromatic values of handsheets made from the fibres after the disintegration for non aged and aged prints in a row from 10, 20 and 30 days are almost linear in the violet area and are in the range of $1.3 a^* - 3.2 b^*$ for non aged to $1.6 a^* - 4.6 b^*$ for 30 days aged print (figure 2).

The prints used in the deinking flotation process were made on uncoated paper with conventional offset inks. Handsheets made from the fibres after the flotation has the colour intensity a little bit smaller than the ones before flotation, and a slight shift towards the blue area is noticed.

Handsheets obtained with processing of non aged, but also aged prints show such a trend. Otherwise, the chromatic values of handsheets before and after flotation were slightly separated from aged ones and moved towards the achromatic area.

Figure 3 shows the results for a system that is different from the previous only by ink composition. In this case, the inks with larger share of renewable raw materials were used.

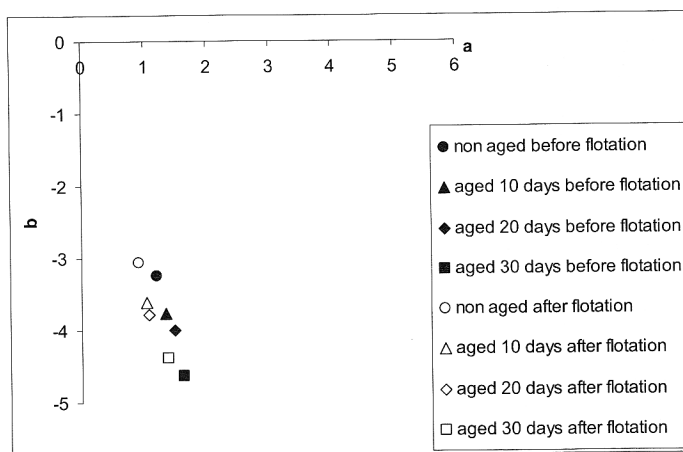


Fig. 3. Chromatic values a^* and b^* for a handsheet made from the fibres before and after flotation, depending on the dynamics of aging (print: uncoated paper, inks with higher share of renewable raw materials)

In comparison to prior results presented in this case the chromatic values are grouped and moved slightly from the magenta towards violet area (figure 3). Chromatic values of the handsheets before flotation are in the range of 3.2 a^* and -3.5 b^* to 4.0 a^* and -4.2 b^* and after the flotation for a small amount going towards achromatic values compared to those before the flotation.

Print for recycling is made on the fine art glossy paper (90g/m²) with conventional colour (figure 4). When non aged and 10 days aged prints compared to 20 and 30 days aged prints are used in processing, grouping of chromatic values of handsheets made of fibres from the recycling process can be seen.

Chromatic values of the non aged and 10 days aged prints are located in the vicinity of achromatic area, while the other group is moved towards magenta.

When the print for recycling is prepared on the same substrate as was the case in the previous example, and for printing is used inks with a larger share of renewable raw materials instead of conventional inks for the handsheets made from fibres before and after flotation chromatic values as shown in figure 5 are gained.

Non aged samples as well as those aged 10 days move towards the magenta area while others do not experience major changes in chromaticity.

Lower efficiency of the flotation process for sample aged 20 days can be seen and a small shift toward the blue area is noticed.

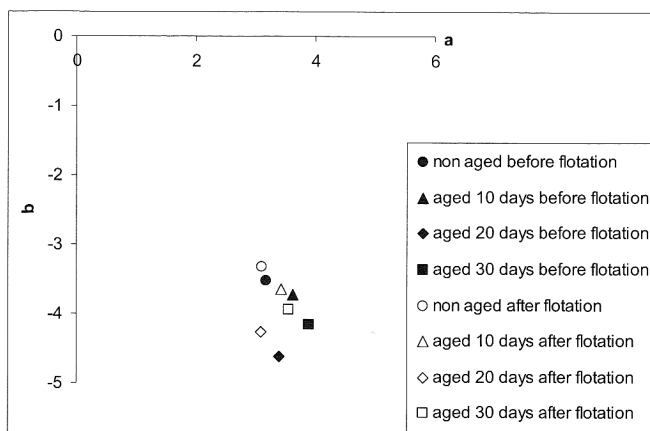


Fig. 4. Chromatic values a^* and b^* for a handsheet made from the fibers before and after flotation, depending on the dynamics of aging (print: fine art glossy paper, 90g/m^2 , conventional ink)

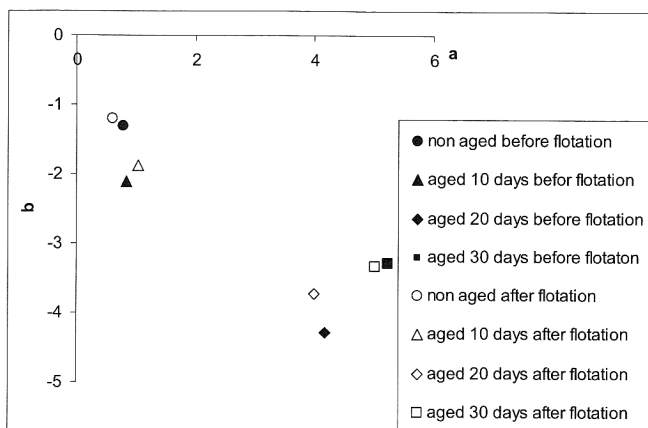


Fig. 5. Chromatic values a^* and b^* for a handsheet made from the fibres before and after flotation, depending on the dynamics of aging (print: fine art glossy paper, 90g/m^2 , ink with larger share of renewable raw materials)

To obtain information about the influence of basic weight and coating of the substrate on chromatic properties of handsheet made from recycled fibres for the printing fine art paper (150g/m^2) is used and the results are shown in figure 6. In this case the focus is on the impact of the process dynamics of the aging prints before recycling, so that the chromatic values of handsheets are grouped for non aged prints, similar values were associated with 10 and 20 days aged prints, while 30 days aged prints are separated with their specific values.

The research results show that handsheet gained from the fibres by recycling process phases with using non aged prints chromatic values are in the orange area, for 10 and 20 days aged prints are in magenta, and for 30 days aged prints are in violet area.

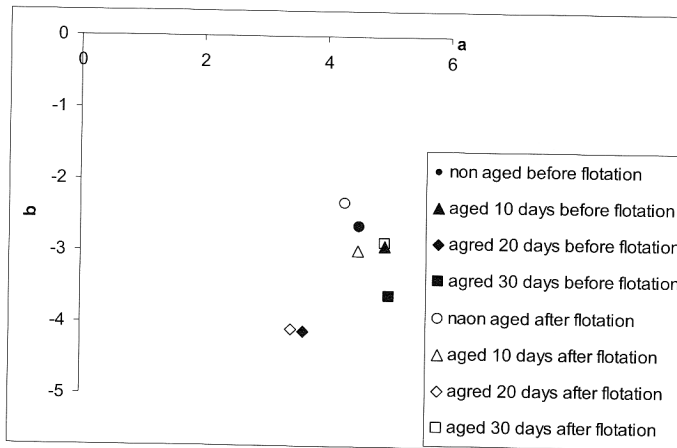


Fig. 6. Chromatic values a^* and b^* for a handsheet made from the fibres before and after flotation, depending on the dynamics of aging (print: fine art glossy paper, 150g/m², conventional ink)

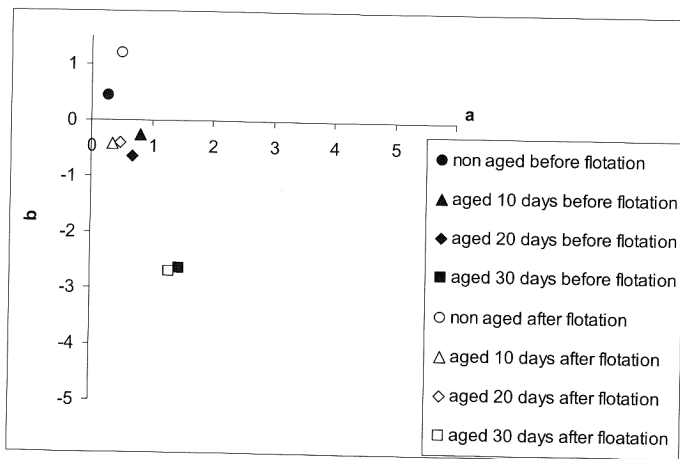


Fig. 7. Chromatic values a^* and b^* for a handsheet made from the fibres before and after flotation, depending on the dynamics of aging (print: fine art glossy paper, 150g/m², ink with higher share of renewable raw materials)

Figure 7 shows chromatic values a^* and b^* for a handsheet made from the fibres before and after flotation on the same substrate that was used for obtaining the results shown in Figure 6, with the difference that in this case ink with higher share of renewable raw materials was used.

Handsheets made of fibres before flotation on fine art paper, 150g/m² with ink with greater share of renewable raw materials, have chromatic values ranging from 2.5 to 4.4 a^* , and from 0.7 to -3.2 b^* . The least affect on chromaticity has deinking flotation for 30 days aged prints.

Overall, the results of research indicate that aging of prints made from ink with a higher share of renewable raw materials with deinking flotation gives fibres of higher chromaticity compared to conventional ink and dynamics of aging prints.

Removing ink from surfaces in the process of deinking depends also on the characteristics the substrate. By prints on coated paper there is no contact between the inks and fibres. The paper coating disintegrates as the recovered paper is pulped and fragments of the ink film are released. Unlike by uncoated paper adhesion of ink on the paper depends on the structure of surfaces, ash content, the type of fibres, as well as the mechanism of drying inks in the printing process.

Offset inks that contain a larger proportion of oxidative drying oils are more difficult to remove from the fibres, and from the results are evident that the composition of ink affects chromatic properties of the fibres. Weaker efficiency of aged prints can be explained with the oxidation processes in which the chemical interactions between the ink and substrate are increased. Also the presence of aldehyde resins in inks causes networking, which can induce covalent bonds between the ink and cellulose through oxidative polymerization over time. In addition, acidic groups of the fibres, as well as in inks can increase the possibility of forming hydrogen bonds, respectively the interaction between ink and fibres.

4. Conclusion

On the basis of the research results the following conclusions were adopted: In the case of recycling prints with conventional ink on fine art matte paper, the handsheet made of fibres after deinking flotation has an almost linear shift towards achromatic area of handsheets with increasing aging time. Compared with a handsheet obtained from the recycled prints on uncoated paper the following difference is observed. At uncoated paper colour loss is significantly slower compared to the coated paper, considering time of aging prints. While the handsheet obtained with recycling of print on 30 days aged coated matte paper is practically achromatic, handsheet obtained from print on the uncoated paper has maintained its relatively strong level of colouration. At the handsheet obtained from prints on the paper with no coatings final effect of aging after 30 days in the case before and after flotation was kept in the area of 1-1,5 a * and 3 -b *, which is still significantly coloured.

The results show that the handsheet obtained from the recycled fibres on uncoated paper with the ink on the basis of renewable raw materials, not aged and 10 days aged, give an even greater shift toward the red area, and then depending on the time of aging for the sheets before and after flotation chromatic values vary very properly and slowly to a neutral gray area. This is specific for deinking flotation with ink based on renewable raw materials.

It was found that the handsheets obtained from the fibres before and after flotation of aged and non aged prints on fine art glossy paper (90g/m²) with conventional ink as well as those based on renewable raw materials with ageing a shift toward the red area is noticed, and with increasing the aging time it goes in direction to the achromatic area. Closer to achromatic area there is a handsheet made from recycled fibres obtained from conventional ink.

The results of research are scientific contribution in the field of deinking mechanism of aged prints made with ink based on renewable raw materials. Application of the

results is important for obtaining secondary raw material of quality that meets the production of fine graphic art papers. Continuation of research is going in the direction of the optimization process through the use of experimental design and creation of statistical models including all other relevant factors, which in the general area engages sustainable design of graphic products.

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