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SCREENS OF OFFSET PRINTS AND INK CONTENT IN RECYCLING PROCESS

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The influence of the screen of the offset colour prints on the recycling effectiveness has been investigated in this work. The printing form contained four parts. Two parts were realized by the amplitude modulated screening with the screen ruling L 60 lines cm^{-1} screen and 80 lines cm^{-1} screen, while the other two were realized by frequency modulated screening (diameter of the individual dot 20 μm and 40 μm). Gloss and mat fine art paper and paper made from the recycled raw materials were used for the preparation of samples. On the basis of the obtained results it can be concluded that the dirt spot number and the area are greater when the print made with AM screening was used for recycling in relation to the print made with FM screenings. Number of the particles formed in the disintegration process of prints has been explained from the aspect of the printing surface coverage. It was proved that in that combination the coating of the printing substrate is an essential factor for the effectiveness of the deinking flotation. The number and the area of the dirt spots as a function of their classes are depleted according to the exponential function used as a fit in one model.

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Introduction

The recycling of waste paper in relation to the production of virgin paper influences the consumption of resources and energy, decreases the pollution of the process water and air, preserves the woods and has the positive economic effect.

The effectiveness of the deinking process itself depends on numerous factors. The following ones have to be mentioned: the printing technique, the ink characteristics, the properties of the printing substrate and the components of the coating. The other influential factors are the kind and quantity of chemicals used in different phases of the process as well as the chemical and physical conditions of the system such as pH value, consistency of fiber suspension, defibering time and the hydrodynamic factors of the flotation process [1].

The size, shape and the surface properties of the dispersed ink particles, the air volume and the size of the air bubbles have special importance for the effectiveness of deinking flotation. The effectiveness of the process depends on the ability of the printing ink adherence on air bubbles and the strength of this bond in order to prevent their detaching and rebinding to the cellulose fibers [2,3]. The surfactants stabilize the air bubbles. The surface of the air bubble and the ink is hydrophobic, while the cellulose fibers are hydrophilic.

The main problem of such a complex process is the effectiveness of the printing ink detaching or the toner detaching from the cellulose fibers, removal of the ink particles from the suspension as well as the purification of the waste water. In the described problems, the majority of authors researched the hydrodynamic factors of the process and the influence of chemical and physical conditions of the system on the process effectiveness, while the influence of the printing techniques and the conditions in printing process have not been studied much [4,5].

The investigation results of the screening processes in offset printing (amplitude modulated screening with the screen ruling L 60 lines cm^{-1} screen and 80 lines cm^{-1} screen, frequency modulated screening with the diameter of the individual dot 20 μm and 40 μm on the effectiveness of the print recycling have been presented. Number and area of dirt spot as a function of their classes are depleted according to exponential function used as a fit in one model. In scientific sense, the work is a contribution to the explanation of the print deinking mechanism in relation to the amplitude and frequency modulated screening used in reproduction in combination with the coated and uncoated papers and paper made from the recycled raw materials.

Experimental

The experimental part began with the design of the printing forms. The printing forms contained four parts. Two parts were realized by amplitude modulated screening with the screen ruling L 60 lines cm^{-1} screen and 80 lines cm^{-1} screen, while the other two were realized by frequency modulated screening (diameter of the individual dot 20 μm and 40 μm). The scale of the whole tone values was done and the samples for recycling were printed on 75 % .

Except the mentioned elements, the printing forms contained the control strip FOGRA 4GS for automatic leading of printing process by means of CPC equipment. Standard screening angles were used in screening in order to simulate completely the conditions of illustration processing in practice. The printing forms were made by standard processes.

Printing runs were printed on offset printing machine Heidelberg SpeedMaster 74 on printing substrates with different characteristics (gloss and matt fine art papers and paper made from the recycled raw materials).

The prints obtained by amplitude and frequency modulated screening were subjected to the recycling. For print recycling the method of alkaline chemical deinking flotation was used, which was described in detail in the previous work [6]. The handsheets were made using a laboratory sheet former, according to standard method T 205.

The Technidyne Color Touch spectrophotometer was used for determining ISO brightness and effective residual ink concentration of the handsheets.

Residual ink size, dirt particles number and ink area were assessed with image analysis software Spec*Scan, Apogee System. This system is utilizing a scanner to digitize image. Threshold value (100), white level (75) and black level (65) were chosen after comparing computer images to handsheet.

Results and Discussion

The characteristics of fibres according to the phases of the deinking flotation process are determined by the image analysis and the results of the total dirt spot numbers are presented in Fig.1 for all the substrates used in printing the samples for recycling.

The image analysis results show that in all the used printing substrates the dirt spot number on handsheet is greater if the print for recycling is obtained by using the AM screen in the graphic reproduction in relation to the FM screens.

The greatest number of the residual particles is on the handsheet made from the recycled fibers of the prints made on mat fine art paper, and the smallest one is on the uncoated paper which contains the recycled fibers of the earlier generation.

With conventional AM screen, amplitude-modulated, the individual dots are spaced at equal distances from one another and only the dot size changes (amplitude). The dots in FM screening have the same size, but are irregularly spaced (Fig. 2 b). In our study we used prints generated by stochastic FM screening method.

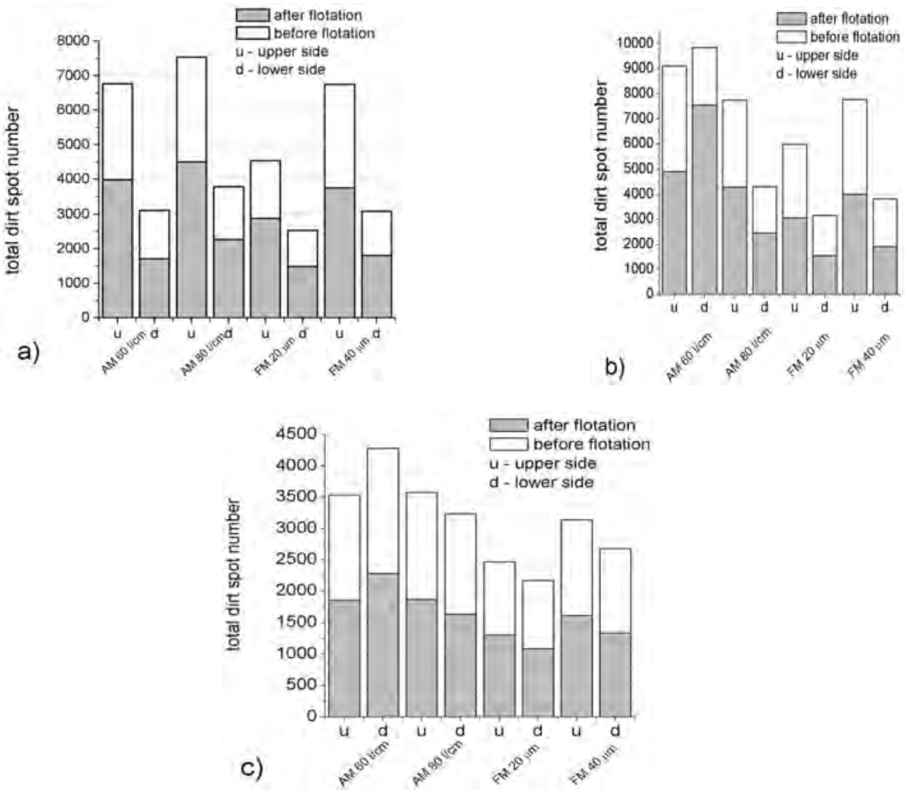

Fig. 1 Total dirt spot number of handsheet made from fiber before and after flotation: a) Prints for recycling on fine art gloss paper; b) Prints for recycling on fine art matt paper, c) Prints for recycling on recycled paper

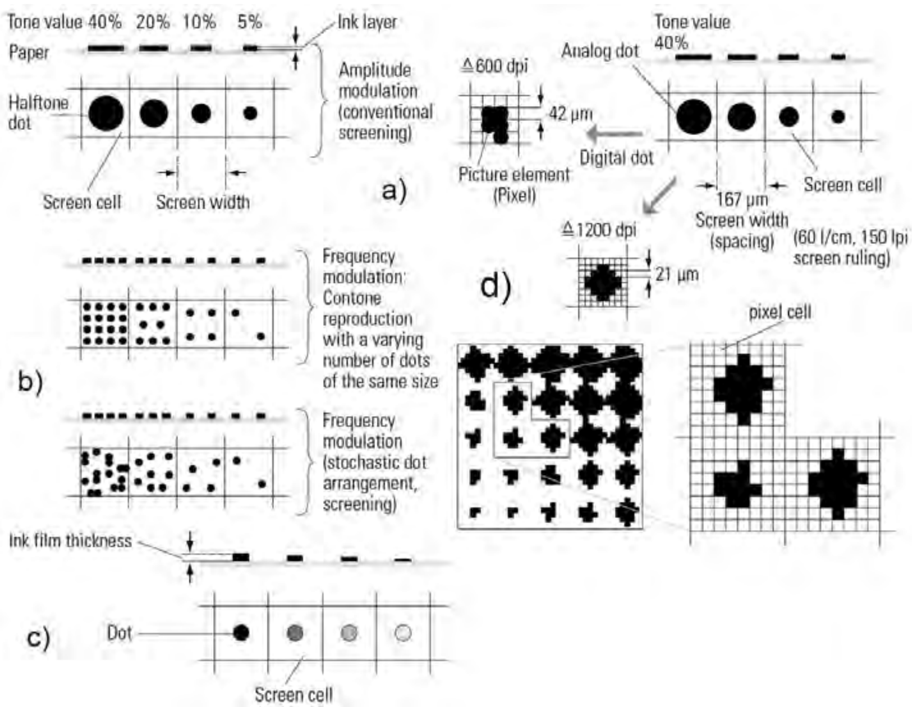

Fig. 2 Screening methods in a modern printing: a) amplitude modulated screening b) two types of frequency modulated screening c) screening with modulation of colour density d) the transition from analog to digital screening [7]

Greater number of particles formed in AM screen can be explained from the aspect of the coverage of the printed surface. In higher tone areas the AM screen elements are so large that a certain overlapping with the neighboring elements happens.

The mixture of two coloured fields generated with transparent CMYK inks occurs on the regions of their overlapping and new RGB spot is formed. In this case the first printed ink better adheres to the paper substrate. The first printed ink is completely (on the whole surface) on paper, while the second printed ink is only partly on the paper and partly on the upper surface of the first printed ink. As the first printed ink is not completely dry at the time of the printing the second ink, the surface crosslinking appears which results in the creation of the greater common ink agglomerates. As the trapping (successfulness of the ink application on another ink) is greater on the coated papers than on the uncoated ones, it is visible that such prints will have the greater share of the secondary printed spot tones.

With FM screens such problem does not exist because the screen elements are of equal size in all the tone areas, and by printing on paper there is no mutual overlapping. With this there are no satellite spot toners.

The coating of paper is an essential factor of the recycling process effectiveness. Besides the before mentioned, the fact must be acknowledged that the coating process assists in dispersing the fillers in the coating. In recycling process dispersants are surface active and together with alkali can lead to acceptable ink detachment from the coated paper. These species can hydrophilise ink containing agglomerates and hinder flotation efficiency as well as contribute to unwanted foam generation and/or stability.

On uncoated paper the adhesion of printing ink to paper depends on paper properties such as surface structure, fiber type, ash content and drying mechanism of the particular printing process. Printing inks, which form firmly sticking, are example offset inks containing large shares of oxidatively drying oils such as linseed oil or soy oil.

In Fig. 3 the surface on handsheet is presented which is occupied by the total dirt particles in relation to the screens used in the print reproduction in combination with the printing substrates. The results show that the dirt particles occupy greater surface on handsheet made from the fibers from the print recycling process which were obtained by the usage of the AM screen in regard to the FM screen. Such results are obtained in relation to the total dirt number, which points at the conclusion that the majority of the dirt particles should be within the lower classes of distribution and within their sizes.

On the handsheet made from the recycled fibers prints obtained by the reproduction with AM screen 60 l cm^{-1} on fine art paper the number of particles greater than 0.04 mm^2 is 141, and the number of those smaller than 0.04 mm^2 is 2707 (the greatest majority of particles 1421 belongs to the class from 0.001 to

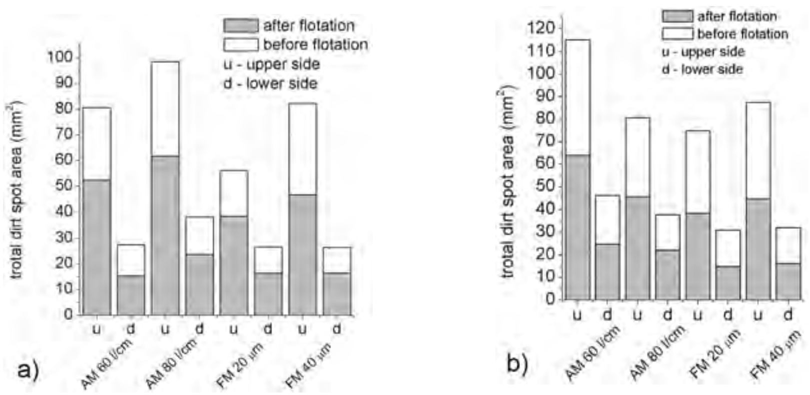

Fig. 3 Total dirt spot area of handsheet made from fiber before and after flotation: a) Prints for recycling on fine art gloss paper; b) Prints for recycling on fine art matt paper

0.006 mm^2), while for the prints with FM screen 20μm the number of particles greater than 0.04 mm^2 is 56, and the number of those smaller than 0.04 mm^2 is 1477 (the greatest majority of particles 1421 belongs to the class from 0.001 to 0.006 mm^2). The range of the class sizes of the residual particles on handsheet made from the fibres before flotation for print on fine art glossy paper is in the range from 0.001 to 0.006 mm^2 . By the flotation the particles from the highest classes are completely removed in some cases. Such case is with prints made by the reproduction with FM 20 μm screen on fine art glossy paper where all the dirt spots are removed up to the class 0.09-0.10 mm^2.

The residual dirt spots influence the ERIC (effective residual ink concentration) and brightness as follows. On the handsheet made from the recycled fibers prints obtained by the reproduction with AM screen 60 l cm^{-1} ERIC value before flotation is 104.0, and after flotation it is 102.0, while for the prints made with FM 20 μm screen ERIC it is 111.8 before flotation and 79.5 after flotation (brightness is 79.6). The number and area of dirt spot as a function of their classes are depleted according to exponentional function used as a fit in one model (Fig. 4).

The fitting equation was used for the model

$$y = y_0 + Ae^{-\frac{x}{t}} \qquad (1)$$

The presented expression was used for the number and the area of the residual particles on the handsheet made from the fibres from the deinking flotation process. The parameter y_0 equals zero because it represents the number of the particles or the areas if the size of particle tends to infinity. But calculation gives asymptotic value of y_0 which slightly differs from zero, which reflects linear influence of overall background. "*A*" is the asymptotic value the particle number and the area have if the size of the particle equals zero. The constant *t* is the chara-

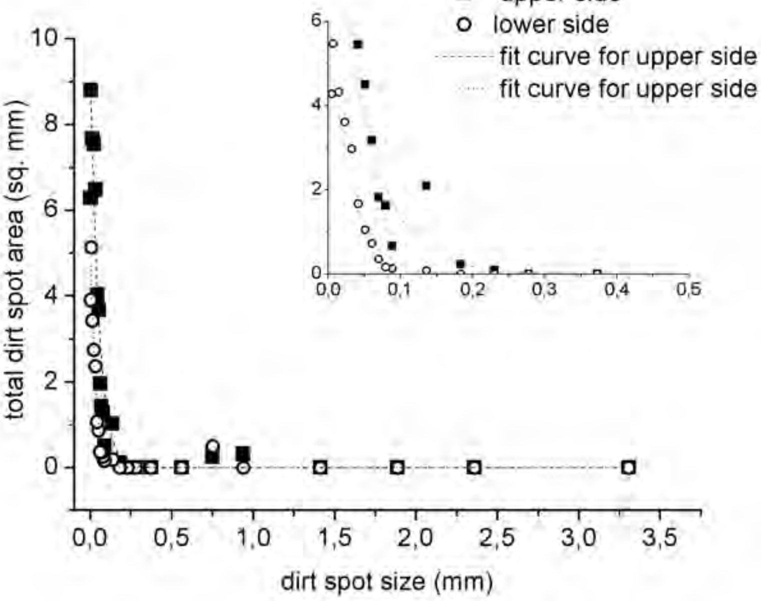

Fig. 4 Total dirt spot area versus dirt spot size. In upper right corner enlarged area which clearly illustrates exponential decay is shown.

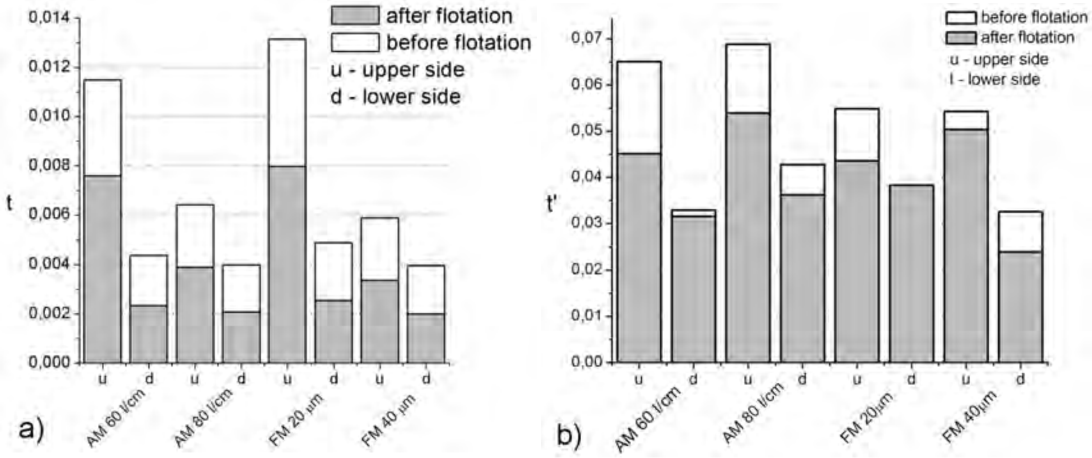

Fig. 5 *t* and *t*' for investigated systems

cteristic value for the given system when the number of the particles is observed, while *t*' is used when observing the areas which the particles occupy on handsheet. The characteristic constants *t* and *t*' include all the relevant factors of the observed system such as: the paper kind, screens, recycling process conditions. The parameters *t* and *t*' present the behaviour of the system regardless of the beforehand defined distribution of particle size classes.

From physical point of view, the exponential decay is natural and expected, which this model proves. It is necessary to point out that the same form of the function describes the particle number per classes as well as their total area, which was not possible to determine beforehand.

Based on the results it can be concluded: the lesser *t* results in quicker becoming poor with particles in each class, i.e., the effectiveness of the deinking flotation process is greater.

The effectiveness of the particle removal is greater when *t* is smaller, i.e., when the function is steeper, which means that somewhat greater particles flotate better than the small ones. The better characteristics of the recycled fibers can be expected in relation to the number of the residual particles and areas which they occupy on handsheet during the deinking flotation of prints by which the FM screen was used (the diameter of the individual dot is 20 μm) in relation to the AM screens.

Conclusion

On the basis of the obtained results it can be concluded that the total dirt spot number and area is greater when the print in AM screen was used for recycling in relation to the FM screens. The results are explained from the aspect of the printed surface coverage. It was proved that in this combination the coating of the substrate is the essential factor of the effectiveness of the deinking flotation process.

The number and the area of dirt spots as a function of their classes are depleted according to the exponential function used as a fit in one model and the results show that the effectiveness of the deinking flotation is greater when *t* (*t*') is smaller, i.e., when the function is steeper which means that something greater particles flotate better than the ones in the smallest classes. Better characteristics of the recycled fibers can be expected in the recycled prints in FM screen (the diameter of the individual dot 20 μm) in relation to the other investigated systems in the frame of the described experimental conditions.

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