Influence of the scanning resolution on image segmentation accuracy for an objective fold cracking evaluation

Magdolna Pál, Dragoljub Novaković, Živko Pavlović, Sandra Dedijer,
University of Novi Sad, Faculty of Technical Sciences, Department of Graphic Engineering and Design, Novi Sad, Serbia

Abstract: *The fold cracking resistance of coated papers has become an important field of investigation, due to the constant production cost optimization in paper industry. Although the fold cracking of coated papers is an important phenomenon, there is no standardized method for quantitative evaluation of the amount of cracking, just a few, newly proposed methods. These methods are based on digital image analysis, with different sample preparation, image pre- and post-processing and evaluation techniques. One of the differences is the resolution of digitalized samples. This paper presents an analysis of the effects of chosen digitalisation resolution of paper samples on the image analysing accuracy for an objective fold cracking evaluation. In order to get more insight, a detailed investigation has been conducted to overview the advantages and disadvantages of higher resolution of scanned samples in the objective fold cracking evaluation process.*

Keywords: *fold cracking, image resolution, quality control*

1. Introduction

The folding process is one of the basic converting operations and participates it is included in the production process in most of the printed products. By folding, paper and paperboard are exposed to high tensile stresses on the outer side of the folding line. These high strains may lead to cracking within the coating layer and these cracks may influence both the visual appearance and the in-plane strength of the paper. Coated papers are more sensitive to cracking during folding than uncoated papers, because the coating layer is not as flexible as the base paper. In extreme cases, when the cracks propagate trough the cross section of the paper, the final products can fall apart along the folds and completely loose their functionality. Therefore the resistance to cracking is a very important property in the converting process [1–3].

Many studies have been published about the factors that influence the fold-crack resistance of coated paper and they include investigations of the mechanical properties and colour formulation of coating layers, the number and thickness of single coating layer [1–5], the fibre composition, thickness and basis weight of the base paper [6, 7] and the cracking mechanism at the fold [8–10], etc. In most of these investigations basic mechanical properties (tensile and compressive strength, bending stiffness, etc.) were tested to compare different experimental setup, but in some studies visual assessments were also applied to determine the amount of cracking. Although the fold cracking of coated papers is an important phenomenon for both paper and graphic industry and there is a huge capacity in computer based quality control due to digital image processing, there is no standardized method for quantitative evaluation of the amount of cracking, just a few, newly proposed methods. These are based on digital image analysis of the paper samples, which were printed with darker colour to improve the contrast between the cracked and undamaged paper surface, folded and digitalised. The amount of cracked surface has been determined by applying different image analyse software [3, 5, 7–13]. Even if these methods share a common fundamental basis, they differ in certain aspects of paper sample preparation (sample size and number, applied printing techniques and colour, folding process, etc.), digitisation techniques (equipment, lighting, colour mode, resolution, magnification, etc.) and evaluation process (image pre-processing, mathematical basis for crack amount calculating, value representing, etc.). One of the digitalization techniques is scanning, which has many advantages like built-in lighting, constant focus along the complete surface, simple handling and easy sample preparation. In this paper a comparative study has been conducted to evaluate the influence of the scanning resolution of scanned samples in the objective fold cracking evaluation process.

2. Materials and methods

Samples of coated papers

The samples were made from glossy coated paper for offset printing with five different basis weights: 90 g/m², 115 g/m², 130 g/m², 150 g/m² and 170 g/m² (Fedrigoni, Italy). The sample papers were selected with the same base stock composition (fibre mixture of the coated paper's core), coating weight and composition in order to simulate the increasing tendency of the surface damages. Before the folding process, all samples were printed in solid tone using standard cyan ink (Sun Chemical) for offset printing in order to enhance the visibility of cracked surface on the fold line. The samples are printed on KBA Rapida 75 offset machine and folded on Horizon AFC546AKT folding machine. The folding process was performed with one buckle folding unit using soft PU foam rubber and steel fold rollers and standard roller gap adjustment. 250 samples of each paper grade were folded in both paper grain direction at standard conditions (temperature of 23 ºC, relative humidity of 55%) 48 hours after printing.

Sample digitalisation

For the purpose of this investigation, a commercial flatbed scanner (CanonScan Lide 210i) has been used in the sample digitalisation process. Using the scanner driver through MP Navigator EX scanning software, 20 images were generated for each paper grade at 8 different resolutions: 4 basic resolution rates (600dpi, 1200dpi, 2400dpi and 4800 dpi) and 4 mid-step resolution rates (1800dpi, 3000dpi, 3600dpi and 4200dpi), thus there were 800 sample images collected for digital analysing. The selection of basic resolution rates was done based on the literature findings. Gidlöf et al. used 600dpi resolution for toner adhesion determination [14]. In their previous studies for on-line and automated folding quality assessment Apro et al. prepared their samples by scanning at 1200dpi [11–13]. Sim et al. [7], Barbier et al. [10], and Rätto et al. [3, 8, 9] used 2400dpi scanning resolution for samples digitalisation in their investigation of coating model analysis, effect of pulp fibre and coating color composition on the fold crack resistance of coated paper. The mid-step resolutions were driven by need to cover the resolution spectrum with finer grain. For this investigation samples folded in cross direction (CD) were used.

The paper samples were placed flat into the scanner and the scanning area was set along the fold line with dimensions of 4 x 25 mm (corresponding to surface of 1cm^2) capturing the cracked line\surface more or less in the middle of the scanning window. The images were scanned in RGB color mode, saved as BMP file with color depth of 24bit. During the scanning all advance image settings (like unsharp mask or image descreening), were turned off.

Image processing and analysing (cracked area determination)

The quantitative determination of the amount of cracked area is based on binary image analysis. The binarized images, needed in this process, were derived from the red channel of the original images (Figure 1a), using simple channel extraction (Figure 1b). The red channel is suitable to distinguish the damaged and undamaged surfaces, since the undamaged surfaces were printed witin fullsolid tone cyan, which does not have red component in the RGB colour space opposed to the damaged surfaces which colour is near white. Therefore the red component could be used instead of intensity component for greyscale conversion process. The binarization was based on the assumption that every not black pixel (has a value above 0) on image belongs to the area of interest (Figure 1c).

a) b) c)

Figure 1: Image preparing procedure: original RGB image (a), red channel from original image (b), binarized image (c)

The cracked areas (fold cracks), denoted as white surface on the coating layer were identified on the binarized images and were determined according to Eq. 1 [Sim]:

$$\text{White pixel percentage [\%]} = A / B * 100 \qquad (1)$$

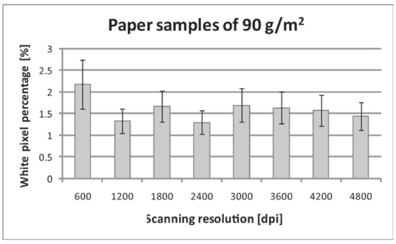
where, A denotes the cracked surface on the sample and B is the scanned area. The average value of the fold crack percentage and its standard deviation were calculated for each paper grade and scanning resolution rate.

In this investigation no smoothing filters or other special filters were applied. All images processing and analysis was done in Matlab by standard built-in algorithms.

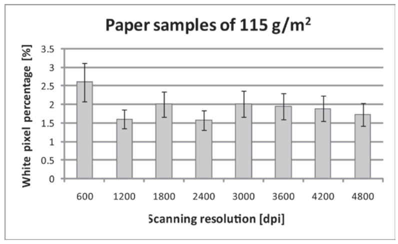
3. Results

The obtained results for fold cracking, as white pixel percentage of samples folded in cross directions are presented in Figure 2a-e, respectively.

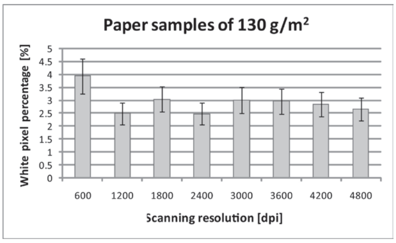
As it can be seen from the figures, by increasing the resolution rate the changes in white pixel percentages for different paper grade had similar tendency. Resolutions of 1200 and 2400 dpi gave very close values of white pixel percentage with nearly same standard deviations for all paper grades. These values were the lowest fold crack percentage, followed by the values derived for the highest resolution (4800dpi).



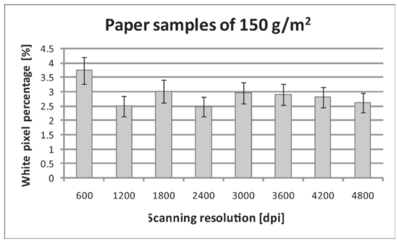
a)



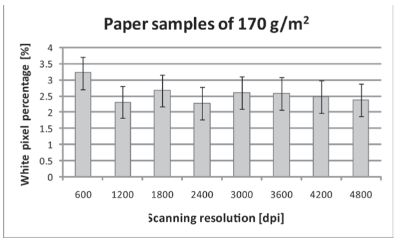
b)



c)



d)



e)

Figure 2: White pixel percentage by scanned resolutions for coated paper samples with basis weight of 90 g/m² (a), 115 g/m² (b) , 130 g/m² (c), 150 g/m² (d) and 170 g/m² (e)

For all the mid-step resolution rates the white pixel percentage values show slight decreasing tendency by increasing resolution, however the values were still higher than those for 1200, 2400 and 4800 dpi all over the sample range. The highest values of white pixel percentage for all paper grades were derived for 600 dpi, which indicates that this resolution is not sufficiently detailed for precise fold crack evaluation, hence will most probably result in over detection.

Assuming that the amount of cracked surface is increasing with the basis weight of the sample, the obtained results were compared for every scanning resolution (Figure 3a-h). As it was expected, samples with higher basis weight suffered more surface damage during the folding process, because they are thicker and the tensile stress on the outer side of the folded paper corresponds to the paper thickness. From the linear regression of data points it can be seen that for the samples scanned at 1200 and 2400 dpi values of white pixel percentage correlate well with basis weight, except of one outlying value which is derived for sample of basis weight of 130 g/m² for all over the sample range. For other scanning resolutions the correlation has lower coefficient R^2.

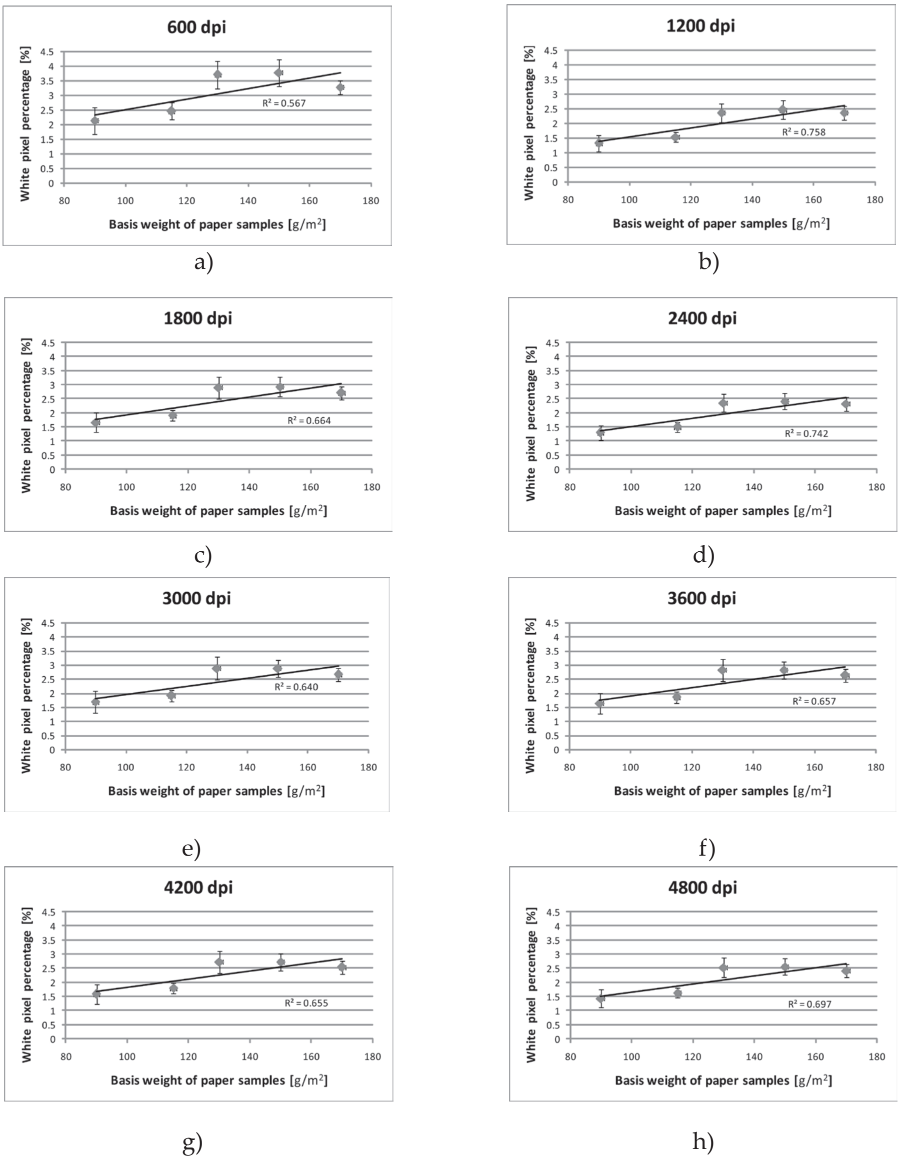


Figure 3: White pixel percentage for paper samples scanned at 600dpi (a), 1200dpi (b), 1800dpi (c), 2400dpi (d), 3000dpi (e), 3600dpi (f), 4200dpi (g) and 4800dpi (h)

4. Conclusions

There are many factors that influence surface cracking during the folding process which are related to the paper manufacturing and to printing and converting processes. Although the surface cracking is an important phenomenon, just a few methods are available to quantitatively characterize the amount of cracking. Some, newly proposed fold crack resistance evaluation methods are based on visual examination of the folded samples using digital image processing techniques. The aim of this investigation was to analyse the influence of the scanning resolution of scanned samples in the objective fold cracking evaluation process. Based on the two presented analysis, as a conclusion it can be conducted, that resolutions of 1200 and 2400 dpi gave the best performance in sense of finest fold crack surface detection and best correlation with the basis weight of the paper samples. It has to be noted that for actual usage of the fold crack detection method, additional image processing is required in form of smoothing filter or more sophisticated segmentation methods whose synergy with the scanning resolution should be further investigated.

Acknowledgments

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5. References

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