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Preliminary analysis of image processing-based evaluation of embossing quality

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Introduction

During the embossing process paper fibres are reshaped into well-defined permanent relief patterns usually by using heat and force. The design can be raised or lowered, flat or sculpted, but also combined with other print finishing embellishments, such as foil stamping or pearlescent coating.

Blind embossing, as the simplest technique among the embossing processes, creates a visible image without colour or foil. The visual sensation and legibility are coming from the shadows created by incident light hitting the edges of the recessed or raised elements on the embossed surface. The greater the relief, the more emphasized the shadow, clearer the visibility.

The quality control of embossing features was done only visually for a long time, but in the recent years it became an important target for graphic instrument manufacturers, focusing on the embossing depth, as one of the most important parameters for high quality processing. The commercially available instruments are fine-tuned, optimized for fast and accurate quality control in real manufacturing environment, however, they could represent an expensive investment for small businesses. A simple and more affordable computer aided visual assessment of embossing quality could be a good alternative, but also it would be a great help for 3D printed or laser-engraved dies development.

Problem Description

This analysis was aiming to investigate the applicability of a simple flatbed scanner and the developed image processing algorithm for embossing pressure analysis, based on the difference between the average grayscale levels of areas under and outside shadows on the previously scanned embossed substrates.

Methods

To obtain objective measure of compression force for adequate embossing quality, an image processing algorithm has been developed. It is based on the idea that embossed surfaces of different substrates can be realistically digitalized by simple flatbed scanning, since during the scanning process, the scanner`s built-in lamp creates shadows on the edges of recessed or raised elements and the embossed image in digital form could be perceived similarly like in real viewing conditions. Moreover, the areas under shadows captured in that way could be analyzed by digital image processing.

The initial hypothesis of the developed algorithm lies on the difference between the average grayscale levels of areas under and outside shadows (shadow-based contrast) and how will these differences change by the rise of the applied compression forces. Additionally, the shadow-based contrast could be used as a reference value to ensure adequate visibility of embossed elements by defining the minimum value of needed contrast.

Results

Figure 1 shows the typical transition of grayscale levels from lighter to darker on scanned images due to increased compression force of the embossing process. The lowest compression force left a very pale shadow (Fig. 1a), while the mid range compression force made a more apparent shadow (Fig. 1b) and the highest applied force resulted in the most dominant shadow formation (Fig. 1c).

Figure 1

Samples of 170 g/m² coated paper embossed with 600N (a), 800N (b) and 1000N (c)

Figure 2 presents the increasing tendency of the average greyscale difference for the increasing values of applied compression forces, while Figure 3 shows the typical set of results for the repeatability tests using the previously selected optimal compression forces.

Due to the extensive amount and similarities between the obtained results, only for die type 1 will be presented here graphically.

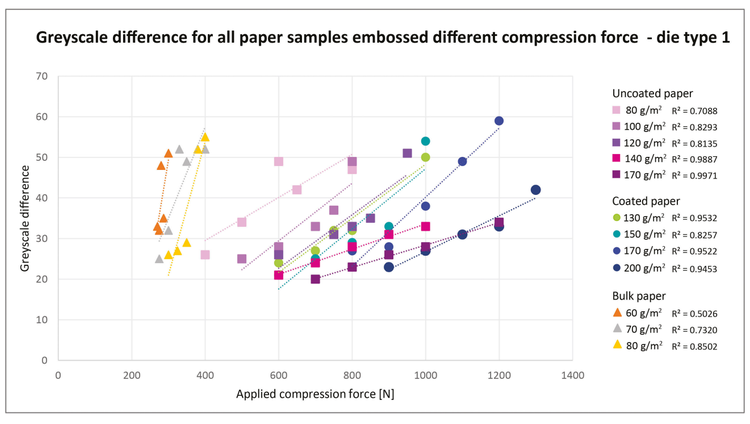

Figure 2

Greyscale difference for all paper samples embossed with different compression forces and die type 1

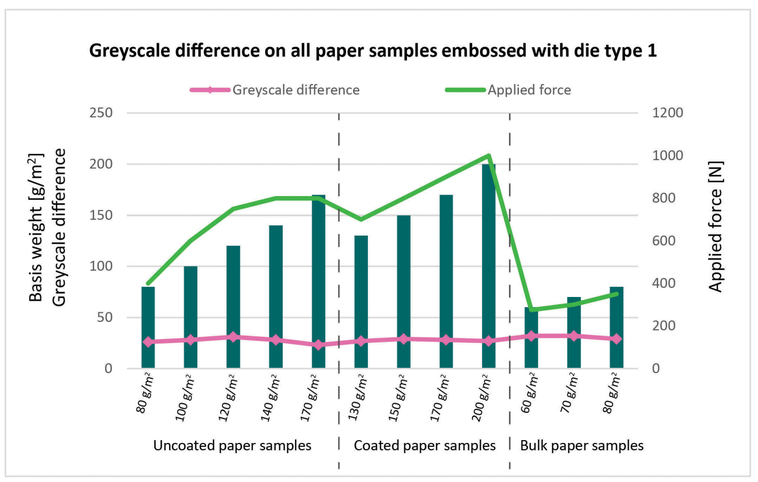

Figure 3

Greyscale difference for all paper samples embossed with optimal compression forces and embossing die type 1

Discussion / Conclusion

After a detailed visual assessment of all scanned paper samples and analysis of the obtained results, it can be stated that a simple flatbed scanner, as an acquisition equipment, can realistically digitalized the embossed paper samples (at least the single-level embossed images).

The values of average greyscale difference (i.e. shadow-based contrast) show increasing tendency by increasing the applied compression force in most of the observed paper and die combinations and with very high values of coefficients of determination. Deviations and low values of coefficients of determination could be noticed for bulk papers in the combination with all embossing dies and for embossing die type 3 used almost on any type of paper sample. On the one hand, these deviations could be associated with the porous and spongy structure of the bulk paper combined with lower surface and overall strength. They usually exhibited poor deformability with significant tendency to creasing, cracking and tearing during the embossing process, even with a small or no compression force increase. On the other hand, numerous surface cracks and/or creases were observed on almost every paper sample embossed with die type 3, where the small-scaled geometric elements on the embossing die punched through the paper at higher compression forces instead of embossing it and generated dark spots on the scanned images. Despite of these deviations in results, they are indicating strong correlation between the shadow-based contrast value and the applied compression force, i.e. the initial hypothesis was correct: it is possible to track changes in the values of shadow-based contrast in accordance to the applied compression force.

Regarding the paper grade, basis weight and type of test elements on the embossing dies, the obtained results imply that the proposed image feature, the shadow-based contrast has a potential to be used in embossing quality evaluation as an objective measure not only for deformation rate tracking, but also as a reference parameter to ensure adequate visibility of embossed elements by defining the minimum value of needed contrast.

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