

Print Quality in Contact and Non-Contact Fixing

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Abstract

In office printers hot roller fusing is favored, whereas non-contact fixing methods are used especially in web printing. The aim of this study was to find out whether there are differences in quality-forming characteristics between contact and non-contact fixing.

Unfused print areas were fixed with a detached hot roller fuser, IR radiation or with a hybrid of these two. The fixing energy was varied with the temperature and fixing time. In addition to basic quality measurements, the micro-scale quality was measured with a multigeometrical optical testing device, which allows different quality variables to be measured from exactly the same spot. Text quality was measured with a scanner-based system. This paper presents the data and discusses the results from the viewpoint of the mechanisms behind fixing quality.

Introduction

The final step in electrophotographic printing is to fix the image areas to the paper surface. In modern office printers the most common fixing method is hot roller fusing. In hot roller fusing the toner is fused to paper with a combination of temperature, time and pressure. The fusing is primarily controlled by the rheological characteristics of the toner.[1,2]

IR radiation is mainly used in applications where contactless fixing is important. In radiation fixing, time and temperature contribute to the fixing phenomenon.[3]

Some digital presses employ a combination of IR radiation and hot roller fixing. Advantages of this kind of hybrid include unaffected image sharpness, no spreading of the toner and a good fixing level on all kinds of paper grades.[4] Hot roller fusing has been found to affect color rendition, achieved coverage level and gloss.[5]

In previous studies, it has been found that the paper grade affects the quality of fusing. Paper roughness has a significant effect on quality, particularly in the roughness range typical of uncoated papers. With smoother coated papers, differences in the composition of the paper surface have been found to result in more variation in printed quality.[6]

The series of work reported here was prompted by observations in practical printing, implying that mechanisms in contact and non-contact fixing differ. The objective is to identify the mechanisms by analyzing the differences in the various fixing alternatives. Consideration is also given to the influence of the paper. Differences between coated and uncoated papers are of special interest. This analysis draws its material mainly from thesis studies.[8,9,10,11]

Methods

The fixing experiments consisted of fixing unfused print surfaces with a detached hot roller fuser[8,9] or an IR radiation device[10]. In both methods, temperature and speed were varied. A hybrid of the two methods was also used. A hot roller was attached either before or after the IR unit. Temperatures or fixing energies were chosen so that they covered the operational window of the equipment. Unfused print areas were obtained from a Lexmark Optra C color laser printer. The test print area was composed of compact black areas, vertical lines and text (TimesNewRoman 11pt).

Quality variables proved to be critical were measured. Optical density and gloss were measured from the solid areas. The gloss values were converted into relative values (gloss contrast) to eliminate the influence of blank paper gloss. Surface roughness was measured with a profilometer.

Solid areas were micrographed with a CCD camera and the surfaces analyzed with an image analysis program. Coverage in the solid areas and tangential edge profile and point spreading in the lines were determined.

In addition to normal quality measurements, the micro-scaled quality was measured with a multigeometrical measurement device[11]. This set-up consists of a stable light source, sample holder and a CCD camera. The angles of incident light and detection can be varied. Besides allowing determinations of several quality metrics, the advantage of this method is that measurements can be made from both fused and unfused surfaces from the same spots without damaging the surface. The measurements include rms (root mean square) values of the variables.

Text quality was measured with a scanner-based method. In this method, an area containing text is scanned with a high-resolution scanner. A quality index is calculated from contrast, point spreading and tangential sharpness.

In all fusing conditions both uncoated woodfree copy papers and coated digital printing papers were used. The coated papers ranged from 80 g/m^2 to 130 g/m^2 and copy papers were 80 g/m^2. The papers were obtained from three different European paper manufacturers.

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Results

Fixing—Hot Roller

Hot roller fusing seems to obey well the much referred theory of Lee[1]. Fusing begins with the melting of the toner particles that are sintered together and spread on the paper surface. Some toner-free areas can be seen in a surface fused at lower temperatures. These white specks arise in the transfer stage. The specks reduce the coverage power and density and are more apparent in uncoated papers.

The toner penetrates partly into the paper structure. The penetration increases with an increase in the fusing temperature. This is clearly because of the lower viscosity levels. When fusing energy is increased even further on uncoated papers, the toner penetrates into the paper to the point that the fibers of the paper appear. This can be seen in Fig. 1. As the fibers emerge, the coverage percentage decreases. The surface of coated papers is less porous which prevents the toner from penetrating into the paper. The movement of the toner melt occurs more in the xy-plane than in the z-direction.

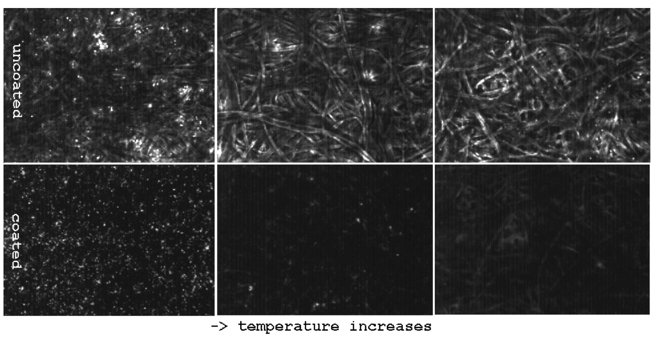

Figure 1. Print surfaces fixed with a hot roller

Surfaces that are fused with a hot roller at higher temperatures are very glossy because of the calendering effect of the nip. Calendering can be physically measured as the decrease in the slope of the topological profile in the print area (Fig. 2a). Relative gloss increases distinctively as the influence of the temperature grows. In all experimental data of this study density correlates linearly with gloss. The density depends on the amount of toner-free areas (Fig. 2a).

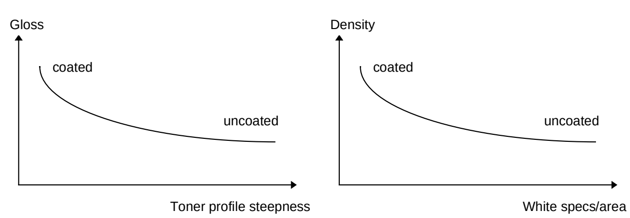

Figure 2. General dependences in gloss (a) and density (b) formation

The number of small-scale variations in density and gloss increases as the temperature is raised. Gloss variation is more pronounced with coated papers. The toner on the peaks of the paper profile gets very glossy as a result of nip calendering. The reflection is specular compared to the diffuse reflection in unfused print areas. If the paper surface is very rough, the toner in the valleys of the surface does not get into good contact with the nip, so the area remains matte.

The nip affects edge raggedness and line spreading of the toner. Point spreading was found to increase linearly as the fusing energy intensifies. Pressure forces the toner layer to spread, but at the same time edges become smoother because some of the satellite particles in proximity of the edge merge. This is proved by the fact that edge raggedness is lower in fused than unfused prints. An increase in the fusing temperature has little effect on the edge raggedness. This suggests that the phenomena are pressure- driven.

Because of the smoothing effect of spreading, text quality is very good (cf. Fig. 7). Text quality is better on coated papers because of their more uniform surface. Over-fixing impairs the quality in the nip.

Fixing—IR Radiation

Surfaces fixed with lower IR radiation energies display an increasing amount of white specks. Toner-free areas can be found in both coated and uncoated papers. At lower fixing energies, these areas have very sharp edges and are rather small and evenly distributed over the whole print area. This causes the coverage percentage to deteriorate. Printed surfaces are rough and hence the finish is very matte.

Wilken et al.[7] have suggested that white specks are formed as a result of local variations in paper surface energetics. Low charge areas were found particularly in areas that had broad hydrophobic fiber bundles. This could explain the toner-free areas in hot roller fusing, whereas the white specks in IR radiation fixing have a very different character. One explanation for this is that as radiation is directed to the paper, the water molecules vaporize and penetrate through the toner layer, causing bubbling which prevents sideways spreading. As the fixing temperature is increased, the white areas diminish in number but they also change character. White areas are now larger and the edges soft. As energy is increased, melting of the toner is faster and the surface temperature of the paper is higher. The changes in the toner layer structure can be seen in Fig. 3.

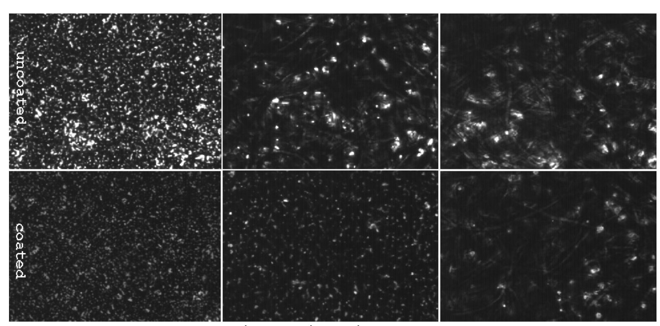

Figure 3. Print surfaces fixed with IR radiation

As in hot roller fusing, the number and quality of white specks control the formation of gloss, density and coverage percentage. Rms gloss is even higher than in hot roller fusing and relative gloss is lower.

Edge raggedness is increased as the fixing energy intensifies. Of the fixing methods examined, IR radiation shows the highest edge raggedness, as was also found in the study by Schleusener et al.[12] This is because toner can scatter from the print area also in the fixing step, unlike in hot roller fusing in which the nip prevents scatter. On the other hand, line spreading is lower in IR radiation than in hot roller fusing.

Text quality (cf. Fig. 7) is poorer than in hot roller fusing. This is due to the more intense edge raggedness. With uncoated papers, text quality is improved with an increase in the energy input. On the other hand, with coated papers, the best quality is achieved with the lowest energies.

Fixing—Hybrid

In studying hybrid fixing, hot roller fusing was used before and after IR radiation fixing. When the hot roller is situated after the radiation unit, it serves as a finishing step. As the toner is already fixed by IR radiation, the nip affects the optical quality variables.

In hybrid fixing, the solid prints are fully covered. Even at lower fixing energies, there are only a few toner-free areas. A hot roller unit combined with IR radiation fixing improves the quality, despite the fact that line spreading increases compared to using the IR unit alone. When the hot roller is placed after the radiation unit, white areas resemble the ones in IR radiation fixing at higher temperatures. Correspondingly, when a hot roller is used first, paper fibers appear as in hot roller fusing. So when the nip is placed after the radiation unit, the print quality resembles very much the quality of IR-fixed prints and vice versa. The relation of the temperatures in the two fixing methods contributes to the final outcome. The best quality is achieved with a moderate IR temperature and a relatively high hot roller temperature.

Discussion

Four major findings were made from the data of the study: First, the basic phenomena in the fixing of the toner to the paper surface are different in the two fixing methods. This is proved by the fact that the effect of an increase in energy on the quality variables differs between the methods. As an example Fig. 4 illustrates relative gloss when the energy input increases. As the fixing temperature is increased, the gloss in hot roller-fused prints increases linearly, whereas radiation-fixed areas reach saturation. The energy increments in both cases are within the operational window.

Moreover, the correlations between gloss and density and their rms values are different. As shown in Fig. 5a, a rise in the gloss level also causes an increase in small-scaled noise. This is explicit, especially in hot roller fusing, although noise is lower at a given level of gloss than in IR fixing. With density the impact is adverse (Fig. 5b). This is because the white specks cause most of the density variation and also control the density.

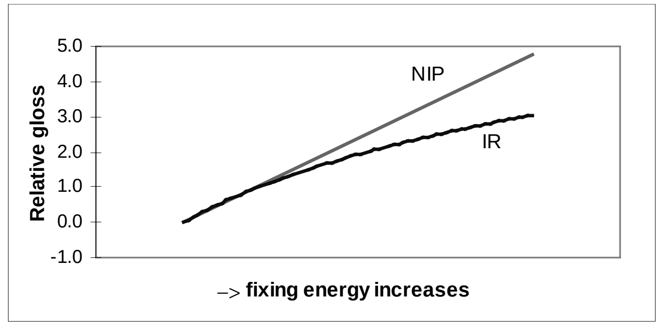

Figure 4. Influence of energy increase on relative gloss level

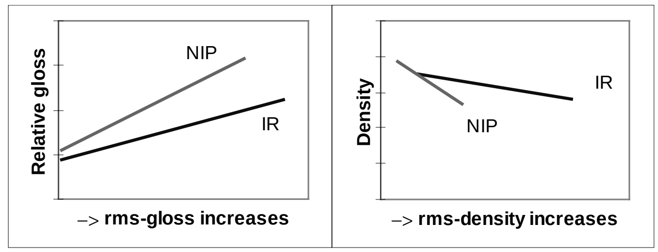

Figure 5. Relations of gloss and density to rms values

The second finding is that the printed surface is formed differently in the two methods. This is illustrated in Fig. 6. As point spreading increases in radiation fixing, the edge raggedness also goes up. In hot roller fusing point spreading has little or no effect on edge raggedness. There is altogether less noise in the lines fused with a hot roller. This is also reflected as better text quality (Fig. 7).

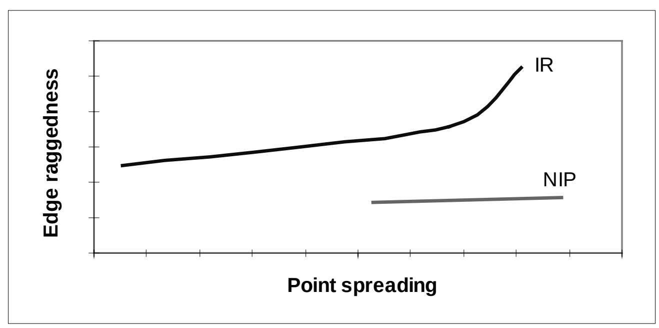

Figure 6. Relationship between edge raggedness and spreading

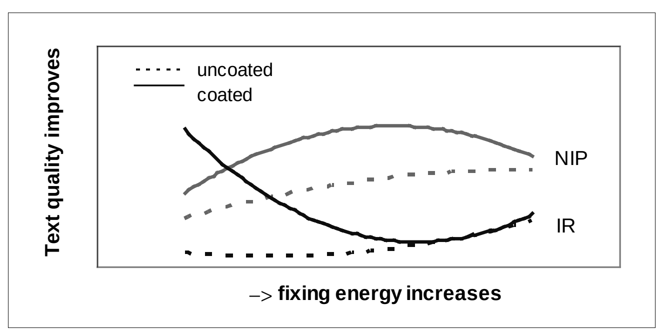

Figure 7. Influence of energy increase on text quality

Visual observations of the surfaces (Figs. 1 and 3) support this finding. As a result of the dissimilar surface formation, there are differences in the interrelations between gloss and density. Fig. 8 shows the relations between relative gloss and density. It is worth noting that the behavior is different in the groups of uncoated and coated papers. In coated papers, the printed surfaces are fairly compact in both methods. In uncoated papers, the lower levels of density at lower fixing energies result in stronger relations.

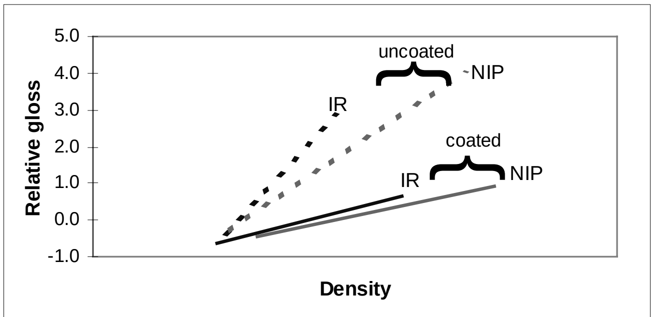

Figure 8. Relationship between gloss and density

The third finding is that in hybrid fixing the first stage has the greatest influence on print quality. The first fixing step appears to determine the basic structure of the surface, whereas the subsequent step adds its own characteristics. For instance, edge raggedness is reduced when the hot roller is situated after the IR radiation unit and increases when the nip is ahead of the unit (Fig. 9). In general, the subsequent step increases the variation and the starting level of most quality variables.

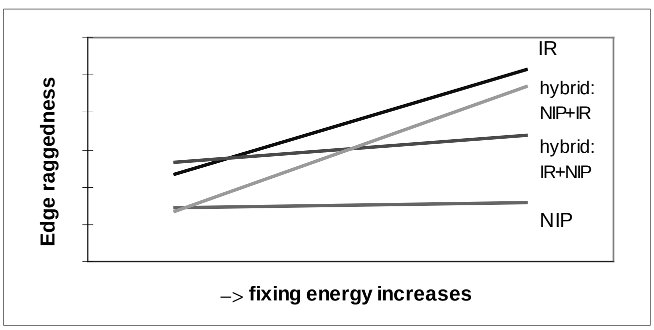

Figure 9. Influence of energy increase on edge raggedness

Finally, differences were found between coated and uncoated papers. In general, better quality is achieved with coated papers because of the smaller amount of toner-free areas, which leads to higher optical density, lower rms density, higher gloss level and enhanced text quality.

Conclusions

The behavior associated with the white specks limits the potential of IR radiation fixing. Both hot roller fusing and IR radiation fixing have favorable characteristics. Overall, hot roller fusing is superior as far as optical print quality is concerned, whereas the hybrid of the two methods may bring an improvement. The IR method is more sensitive to fixing conditions and it involves more noise in both compact areas and lines. The advantages of radiation fixing are mostly related to the process technology.

The uncoated papers examined in the study were more homogeneous as a group, but displayed poorer print quality overall. Coated papers are more sensitive to variations.

In some quality variables, such as gloss, there is a trade-off between gloss level and gloss noise. Breaking this dependence is one of the future challenges in electrophotographic development.

Acknowledgements

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Biography

Katja Sipi received her M.Sc. degree in Graphic Arts Technology from the Helsinki University of Technology (Finland) in 1998. She has continued her work in HUT´s Laboratory of Media Technology as a research scientist and is working on her post-graduate studies. Her current work involves analytical studies of interactions between the toner surface and paper structure.