Paper Transport in Duplex Color Radiation Fusing, Continuous and Flash

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Abstract

We had reported earlier (NIP 18) the use of high intensity continuous radiation and pulsed radiation for color independent radiant fusing. We had found that there is a potential if special developed sharp melting dry ink is used.

At duplex fusing of sheet substrates with electrophotographic engines of duplex loop type the paper passes twice the fusing station with the risk of reheating the first image above softening point. We have analyzed different methods of paper feeding in the fusing area: With radiant fusing the heating time is relatively long with the risk of backside damage. Thus a non-contact paper feeding in the heating zone followed by a non contact paper feeding in the following cooling zone is required.

At flash fusing the energy is incorporated into the surface for short time intervals only and backside problems are not expected. To prove this we evaluated the time dependant backside temperature of the substrate after flash fusing with a fast pyrometer. We could prove that backside image artifacts of toner back side layers in full color printing start well above the flash energy density necessary for fusing. Thus conventional contact paper transport means like Kapton® belts are sufficient for duplex color flash fusing of sheet materials.

Introduction

Fusing is the fourth step of the electrophotographic process.[3] Fixing of the dry toner powder is a process that includes softening, sintering, spreading, penetration into the paper and re-solidification. The complete process of fixing and matching the image quality as far as it is fuser related we call fusing.[1]

For industrial color digital presses the demands regarding paper processability are widened compared to office and computer output printers and include paperweight up to app. 300g/m² and a broad variety of substrates including coated and textured papers. For these applications a variety of non-contact fusing technologies are used or described besides roller fusing like IR- and flash fusing (Figure 1) but hot roller fusing is still dominant.

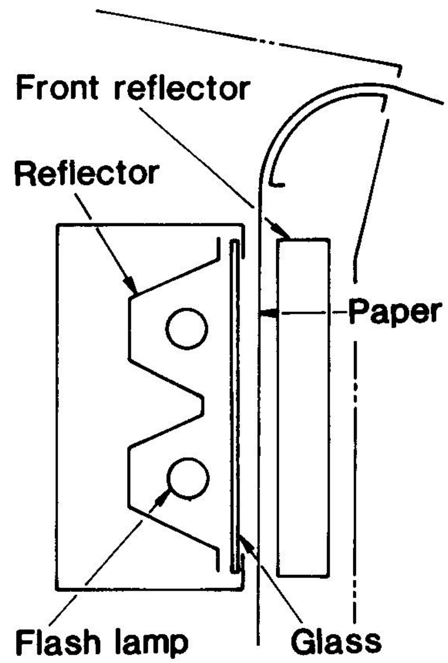

Figure 1. Structure of color flash fuser[6]

Limited reliability and high running cost of roller fusing for high quality printing color motivated us to evaluate non-contact radiant fusing methods using flash or continuous uv-radiation for their potential as future fusing technologies for color production printing.[1]

In a non-contact fusing process the toner has to flow without pressure. That requires a toner with low melt-viscosity that we call "Sharp Melted Dry Ink" (SMDI).[1]

Depending on the lamp type, lamp geometry and the process speed the heating time in non-contact flash or radiant fusing is in the range of 1 ms – 400 ms. In cut sheet printers with duplex loop[5] the paper passes twice the fusing station. The first image maybe heated again above the glass transition temperature (Tg) during fusing of the second printed image. As a consequence the first printed image could be damaged during fusing of the second printed image by any contact paper transport devices.

Flash fusing using single or multiple pulses in the range of 1ms has the potential to keep the backside temperatures below the glass transition temperature of the toner to avoid smearing of the toner on the paper transport means. To prove this assumption we evaluated the time dependant backside temperature of the substrate after flash fusing with a fast pyrometer.

At radiant fusing the heating time is in the range of 100ms – 400ms causing the first printed image to be heated again above the glass transition temperature (Tg) during fusing of the second printed image. A possible solution is the use of a non-contact paper path device for the fuser and the cooler behind the fuser or the use of UV-curing toner.[2]

Flash-Fusing

For the flash fusing experiments the flash fusing breadboard described earler[1] were used.

Experimental Set-Up

The flash lamp housing was orientated with the flash going upward. A paper was held at an angle of 20° above the flash lamp without support to be able to measure the backside temperature of the paper. A fast Pyrometer (sampling rate up to about 1 kHz) has been installed to measure the surface temperature (of toner or paper) as a function of time (Figure 2).

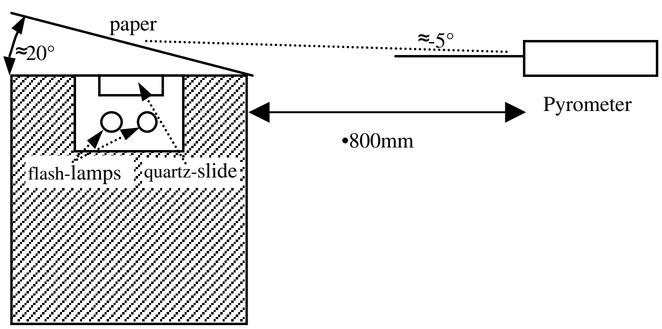

Figure 2. Experimental setups to measure paper backside temperature at flash fusing

Materials

The following paper types were used for this evaluation:

1. coated wood containing paper 65g/m²
2. coated wood free paper 130g/m²
3. uncoated paper 220g/m²

The paper was printed as 100% patches of black toner either on one or on both sides to achieve maximum absorbance of the flashlight.

A Xe-Hg flash lamp was used resulting in a flash energy of 2.4J/cm² in the middle of the fusing patch that is sufficient for fusing of this kind of samples.

Experiments and Results

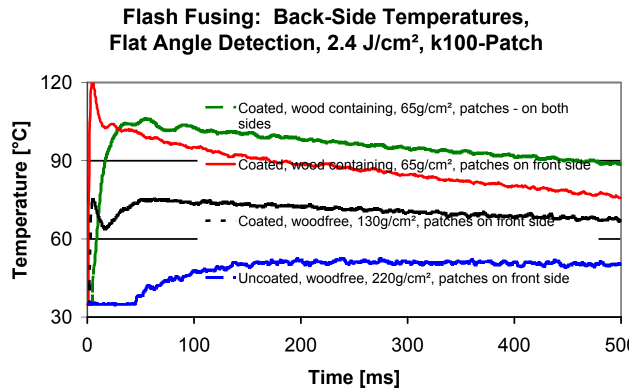

Figure 3. Time dependence of backside paper temperature after flash fusing for different conditions

The time dependence of backside paper temperature after flash fusing was measured and is plotted for different conditions in Figure 3. The measured temperature is a mixture of the paper temperature, the temperature of the toner (if the paper is toned) and the transmitted infrared radiation through the paper. At single side printed 65g/cm²- and 130g/cm²-paper a peak of IR-light from the lamp transmitted through the paper is seen. Double sided printed 65g/cm² and 130g/cm² do not show this effect as the transmitted IR-intensity gets lower if the paper and/or the toner layer are getting thicker. The temperature increase on the backside starts delayed.

The backside temperatures of the papers at flash fusing after the initial peak are as following:

Paper	Maximum backside temperature
coated wood containing paper 65g/m²	104°C after 35ms
coated wood free paper 130g/m²	75°C after 55ms
uncoated paper 220g/m²	52°C after 200ms

For thin paper without support backside temperature in the critical temperature range are achieved. Backside temperatures of supported paper are expected to be lower as the support is working as a heat sink. To clarify this point, fusing tests on uncoated 80g/cm²-paper were performed. The toner used was a sharp melting dry ink[1] with layer thickness of 290% with is the maximum layer thickness of four-color prints when under color removal (UCR)[3] is used.

The sample paper was electrostatically tacked onto a Kapton®-foil. The flash energy density was increased stepwise in 0,5J/cm² steps up till backside artifacts appeared. The pulse-with of single pulses was 2.5ms. Longer pulses mean double pulses of 2.5ms each with that distance. The energy where image artifacts started is listed in the following table:

Flash duration [ms]	**Flash energy density** [ms]	**Backside artifacts**
2.5	4.8	Glossy spots
10	4.2	Sticking of toner spots on Kapton belt
100	5.4	Glossy spots
1000	6	Glossy spots

The results indicate that backside image artifacts of toners start well above the targeted flash energy density (of app. 3J/cm²).

Radiant Fusing

We have evaluated the use of a non-contact paper path device for the fuser and the cooler behind the fuser[6] and alternatively the use of UV-curing toner.[2]

Non Contact Staggered Paper Path

The transport device has several transport rollers to move the substrate in the area of the heater along the transport path. The transport path has at least two melting areas, which-viewed in the substrate transport direction-are located in succession and in laterally offset to one another. The toner image is therefore not completely melted and fixed in one process, but at least a two-part melting process take place in which only one band of the toner image is melted at a time. This makes it possible to arrange the transport elements distributed around the melt areas of the heater. This means that no transport elements or other guide elements come into contact with the top and bottom of the substrate in the melt areas of the heater and in the cooling areas.

When the toner image on the top of the substrate is melted there maybe another toner image on the bottom of the substrate, which remelts and thus cannot stick anywhere since it has no contact with the surface. Until the first and/or second toner image comes into contact with the transport element or another surface, it is cooled down so far that there will be no adverse effect on the image quality or sticking of the substrate on this surface. Sticking of the toner images to a surface, for example to a transport element, is essentially precluded, since contact only occurs when the toner image is in the solid state again.

The melt areas just contact each other or overlap one another slightly on the toner image to be fixed. This adjustment had to be optimized to avoid image artifacts due to remelting of the already fixed toner.

In the heater where the toner image is melted without contact, the toner image is exposed to radiation mainly in the uv range.

Figure 4 shows a schematic view of the transport path of the substrate (not shown) with the functional elements of the heaters and coolers. The fixing area of the fixing device in the substrate transport direction is divided into a total of five zones, three transport zones and two heating/cooling zones, which each extend over the entire width of the substrate transport path. In a first fusing and cooling area 2 two stripes of the substrates are heated, fused and cooled down below the glass transition point. The substrate is then transported into a second fusing and cooling area 4 where three stripes of the substrates are heated, fused and cooled down. Finally five toner image sections, which are the same width, are melted and fused, each of the melted toner image sections slightly overlapping the adjacent toner image section so that no unfixed toner image sections remain.

For transportation of the substrates in this case roller pairs are used. Above the rollers shown there is a second set of rollers.

Using this technology double sided non contact fusing technologies with long heating times where paper back side temperatures exceed the glass transition temperatures of the paper are possible.

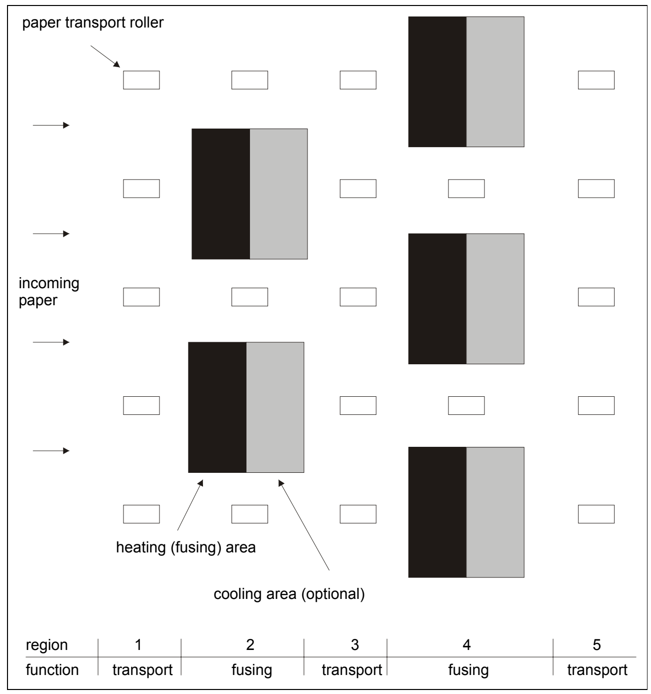

Figure 4. Schematic view of the staggered transport path with action areas of heaters and coolers

UV-Curing Toner[2]

UV-curing of suitable toner[8] enhances the glass transition temperature by the curing process. Above that temperature the toner is transferred into a rubber structure so that no more image artifact occurs when the toner is heated a second time.

A first image is transferred on a substrate sheet. Then, this toner is heated up to its glass transformation temperature or a temperature above it. In this process, the toner is fused until a certain gloss becomes set. Then the toned substrate is illuminated with ultraviolet radiation. Thus the original glass transformation temperature shifts to a higher temperature level as a result of the cross-linking of its polymer chains. Parallel the viscosity of the toner increases so that this toner

1. softens at a higher temperature when it is re-heated and
2. obtains a rubber-like structure.

After the toner has then been fixed to the first side of the substrate, a second image is transferred to the other side of the substrate. In the second fusing step the toner on the second side will be fused and cured. The toner already fixed onto the first side of the substrate can no longer become liquid, but stays highly viscous when heated above its new glass point. Thus it can be ensured that the toner applied and fixed onto the first side of the substrate does not smudge on its support, or experience a change in its gloss, by the fixing of the toner on the other, second side of the substrate.

A breadboard for non contact duplex fusing of toner layers is shown in Figure 5 consisting of a image creating and transfer means (4a-d), melting station for softening the toner layer (3), curing means for cross-linking the toner (2), means for cooling the paper below Tg of the toner (5), and where the paper circulates back from the cooling equipment (1) to the (first) image creating and transfer station (4d) via a duplex loop.

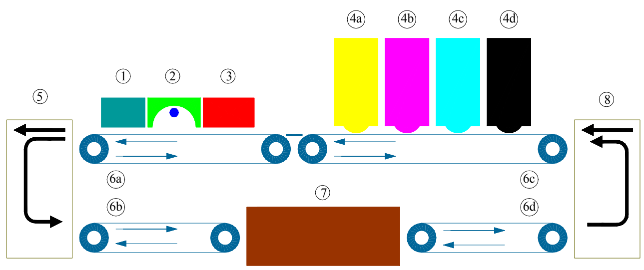

Figure 5. Breadboard for duplex color printing using UV-curing toner

UV-enhanced radiant fusing – as we have used it in our above mentioned radiant fusing experiments – can take over the role of heating and curing so that no separate equipment for heating is necessary.

If the heating and the curing means keep separate the gloss can be influenced in certain limits

When the time and/or intensity is not sufficient for flowing to an even layer of the toner before entering the curing station the surface topology of the toner is frozen in the curing station. By modifying the energy input in the melting step or the time between start of melting and start of curing the surface topology and thus the gloss can be modified.[4]

Comparison

Comparing flash and radiant fusing regarding backside temperature and paper path requirements there are differences:

Backside Temperature: At flash fusing the backside temperature of supported does not exceed critical temperatures for backside image artifacts. For continuous radiant fusing the backside temperature exceeds this limitation

Paper Path: For flash fusing "simple" contact paper transport can be used. For radiant fusing a non contact paper path like our staggered paper path has to be used. Contact paper path needs other approaches like (uv)-curing toner.

Conclusion

We have analyzed paper path requirements for cut sheet printing with flash fusing as well as with radiant.

We have found that for flash fusing a "conventional" contact paper path can be used whereas radiant fusing needs a non contact paper path designs like our proposed staggered paper path or the use of UV-curing toner.

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Biographies

Detlef Schulze-Hagenest received his Ph.D. in Physics from Kaiserslautern-University in 1980. Since 1980 he is working in the field of processes and materials for electrophotography. He is currently Senior Engineer Advanced Technology at NexPress GmbH, Kiel, Germany. He is a member of the IS&T.

Domingo Rohde received his diploma in physics in 1994 and joined Heidelberg Printing Machines in 1997 and later NexPress in Kiel, Germany. Since this time he worked for the Advanced Technology department dealing with non-impact printing technologies. Currently he is the chief engineer of the Advanced Technology department of NexPress in Kiel.