New Developments in Thermal Transfer Imaging

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Abstract

Thermal Transfer is a digital printing methodology used in a variety of commercial and industrial printing applications. Some applications of thermal transfer, such as color office printing, have been displaced by other digital printing methods such as inkjet and color electrophotography. However, thermal transfer remains the dominate printing technology in other areas such as auto-identification, barcode, flexible packaging, tag and label printing. The reasons for this dominance will be discussed and include printing speed, printer reliability, broad receiver latitude, high image durability and low ribbon cost. Unlike other digital imaging methodologies, thermal transfer printing supplies are competitively produced by a number of different manufacturers. This has fostered a great deal variety of consumable offerings and very low pricing. Thermal Transfer printing is also evolving to serve a diverse number of niche digital printing applications such as on-demand CDR/DVD printing and ceramic imaging.

Introduction

Thermal Transfer Printing is a process in which location specific heating of a ribbon causes the transfer of colorant to an image receiving sheet. Location specific heating in this digital printing technology can be accomplished with either a thermal printhead (linear array of resistors) or a laser. There are two main embodiments of this technology, thermal dye transfer, a process capable of continuous tone printing, and thermal mass transfer printing, a bimodal printing process.

The development of Thermal Transfer (TT) as a digital printing methodology began in the early 1980's. While both thermal dye transfer and thermal mass transfer have several early patents, the latter was first commercialized in the early eighties while the former was not released till the late eighties and was not fully developed until the nineties. This paper will focus on thermal mass transfer printing or thermal transfer for short. The first application for this digital printing technology was for word processor printers. However, it quickly evolved into a variety of other commercial and industrial printing applications. Some applications of thermal mass transfer, such as color office printing, have since been displaced by other digital printing methods such as inkjet and color electrophotography. However, thermal transfer remains the dominate printing technology in other areas such as auto-identification, barcode, flexible packaging, tag and label printing. The reasons for this dominance will be discussed and will include printing speed, printer reliability, broad receiver latitude, high image durability and low ribbon cost. Unlike other digital imaging methodologies, thermal transfer printing supplies are competitively produced by a number of different manufacturers. This has fostered a great deal of variety of consumable offerings and very low pricing.

Discussion

Color office printing has undergone a rapid technology substitution from thermal transfer to inkjet over the last 5 years. The chief advantage of inkjet printing is that there is very little waste of colorant, compared to thermal transfer printing. If you are only printing on 10% of the page, then you only use a proportional amount of ink. In contrast, thermal transfer printing typically requires a 1:1 area ratio between the ribbon and the substrate. Thus, if you are only printing on 10% of the page, 90% of the ribbon is wasted. This was exacerbated in color thermal transfer printing where, 3 or 4 color panels were required to print a full color page. This tremendous waste of ribbon, perhaps up to 360%, made color thermal transfer an attractive target for substitution by inkjet. In addition, color thermal transfer also required each color to be printed separately, making the process very slow. Inkjet printing, in contrast, can use separate printheads to print all the process colors simultaneously.

Inkjet printing has yet to have any significant penetration into monochrome tag, ticket, barcode and label printing; however, while inkjet ink is inexpensive to manufacture, it supports a high level of profit for the OEM's. Because the OEM's typically hold the intellectual property on the ink and the printers, they are able to virtually eliminate after-market competition on the inks. Competition in the thermal transfer ribbon business has driven down end user pricing significantly over the last 5 years. Most thermal printers can accept ribbons from any source. Customers can choose from a variety of ribbon types supplied from several different manufacturers. This allows them to trade off ribbon performance with ribbon cost.

Ink jet printing typically requires about 11cc of ink to completely cover 1 square meter. At a cost of $500 per liter for ink, an end user would spend $5.50 to completely cover a 1 meter square print with a single color. A typical black thermal transfer ribbon would cost about $0.40 per square meter. Thus one can see the advantage of using thermal transfer. Typically tags, shipping labels and bar codes are printed between 10 and 25% coverage. This would reduce the inkjet cost to $.55 to $1.32 per square meter, still more than the $0.40 they would spend on a single thermal transfer ribbon.

Thermal transfer printers use parallel printing (printing one line at a time) and commonly operate in the range of 15 cm/sec to 30 cm/sec. Some TT printers for the flexible packaging market can print at 56 cm/sec. In comparison, Inkjet printers use serial printing and have to scan the printhead back and forth across the page. These printers can only add printing speed by increasing the number of printheads. This can greatly increase the cost of the printer. Typical office type Inkjet printers operate at speeds of 3.8 cm/sec.

Thermal transfer printers are highly reliable. They are designed to operate in a wide range of environments (Shipping Docks, Factory Floors, Offices and Homes). These printers have very few moving parts as they are parallel printers, printing one line of information at a time. The linear thermal printheads are very durable as well, often printing 50 km of or more of substrate before replacements are necessary. Another reason for the high reliability of these printers, is the separation of function built into the ribbons. The backcoating on the ribbons controls the printhead-ribbon interface. Such backcoats are designed to lubricate the printhead over the wide printing temperature range (100^o-400^oC), providing a coefficient of friction which is relatively independent of temperature. The face side of the ribbon contains the ink coatings, providing the desired printing characteristics (speed, durability, color, etc.). In contrast, inkjet inks must combine both functions. This greatly restricts ink formulations latitude and reduces the overall reliability of inkjet printheads. For example, it has not been possible to formulate white inkjet inks because the physical nature of the TiO_2 pigments required for these inks tends to not generally be compatible with inkjet printing technology. The ideal particle size for TiO_2 is about 300 nm, enabling the pigment to efficiently scatter visible light. The ideal pigment size for an inkjet ink is about an order of magnitude smaller, to help prevent clogging of the ink jet printhead nozzle. Additionally, the density of TiO_2 is rather high and thus, it tends to settle unless the viscosity of the ink is very high. Since Inkjet printers cannot tolerate high viscosity inks, this makes white inkjet inks doubly impractical. Because the white pigments are on the imaging side of a thermal transfer ribbon, no such head media interface problems exist. A number of white thermal transfer ribbons have been on the market for some time.

A new trend in color thermal transfer printing is to develop multi-head printers to enable process color without the use of panelized ribbons. Some examples of such printers are the TEC B572, the Matan Sprinter B, the Datametrics Condor, and the Asto-Med Sundance. Some of these printers also offer ribbon saver capability so that when a color is not required, that printhead is lifted and the ribbon is saved. This leads to much better ribbon utilization, making thermal transfer very cost competitive with process color inkjet printing. These printers typically operate at 2.5 to 5.0 cm/sec. With printing widths as wide as 0.91m, these printers can produce as much as $42M^2$ sq. ft. per hour of 4 color output. Serial thermal transfer printers have also been developed mostly for the signage business. While these printers are rather slow, they offer better ribbon utilization by only printing the colors which are called for in the image. The main advantage of serial thermal transfer printers is that they are typically rather inexpensive compared to multi-head parallel thermal transfer printers.

Thermal transfer printers can print onto a wide variety of paper and synthetic substrates. These substrates need not be coated to achieve good printing performance. In contrast, inkjet printers require expensive coated papers to achieve high quality barcode printing. There is a very limited selection of tag stocks for IJ printing. Synthetic supports must be coated with an expensive ink receptive layer if aqueous inks are to be used. Solvent based inks can be used on synthetic substrates, but these inks pose an indoor air pollution risk because of their high VOC content. Nearly any flat substrate, including PTFE (polytetrafluoroethylene), can be printed on using thermal transfer printing. The fact that increasing temperature lowers the surface tension of an ink is primarily responsible for this great capability. Thermal transfer inks are melted or softened by the heat of the thermal printhead. The print energy is typically optimized for a given ink/substrate pair. In general, the thermal transfer temperature is raised high enough so that the imaged ink fully wets the substrate. Once cooled, the ink solidifies, adheres to the substrate, and releases from the ribbon.

There are a large variety of ribbon types for thermal transfer printing. These ribbons range from simple general purpose wax ribbons for label printing, to high performance resin types for printing outdoor signage. In contrast, most inkjet printers are optimized for only one type of ink. This restricts the use to a much more limited set of applications for an inkjet printer compared to a thermal transfer printer. In general, thermal transfer printing provides exceptional print durability on a wide variety of substrates. General purpose, wax based thermal transfer ribbons are typically used for printing shipping labels, bar codes, tickets and tags. These images are often subjected to environmental (rain, heat, humidity, etc.), mechanical (smudging, scratching, etc.) and chemical (fingerprints, cleaning agents, etc.) stresses in their normal use. These images, printed on inexpensive natural and synthetic substrates, show exceptional durability to these stresses. Such image durability has been difficult to duplicate with other digital printing technologies at comparable costs/image. In contrast, the durability of thermal transfer ribbons may be further enhanced by incorporating compatible resins into the ink formulations. These so called premium ribbons have higher levels of scratch, smudge and chemical resistance needed for more demanding applications.

Thermal transfer ribbons may be formulated for demanding applications like outdoor signage. Such ribbons are typically formulated from UV resistant high polymer resins and organic pigments. Images printed onto typical outdoor substrates line PVC (polyvinylchloride) are extremely fade resistant and don't require expensive over-lamination. Since the colorants are not water soluble or pH sensitive, they are retained in the resin binder during their outdoor service. The particle size of these pigments is extremely small, allowing for outstanding subtractive color gamut. After the equivalent of 1 year's outdoor exposure in southern Florida, in an Atlas Weatherometer, the subtractive primaries color change for such thermal transfer images on PVC is in the range of 2 to 15 delta E.

Thermal transfer is also branching out into areas where its attributes provide a competitive advantage. For example, while numerous patents exist on the use of inkjet for digital printing of CD's and DVD's, thermal transfer printing has been much more successfully applied. Several printers from Rimage and Primera have been designed to digitally print directly on CD's and DVD's with thermal transfer printing. The use of resin based inks in this application yields images which are highly durable. These ribbons are able to print onto a wide variety of discs manufactured by this industry. In contrast, direct inkjet printing of CD's is restricted to discs which are specially coated with ink receiver layers. Even so, such inkjet printed CD's are easily damaged if exposed to any amount of water, for example a damp finger.

Thermal transfer is used to digitally print variable information directly on apparel labels. Examples of such printing include apparel care instructions, size, lot, vendor and other relevant information. Typically, substrates included smooth woven polyester, dip coated nylon and polyurethane. Specially formulated resin thermal transfer inks adhere well to these coated and uncoated fabrics giving good wash fastness and steam resistance. New thermal transfer technology has been disclosed which can be printed directly onto fabrics with high levels of durability. While inkjet has also been widely used in the area of fabric printing, typically this is done indirectly, utilizing a transfer sheet.

In the future, thermal transfer printing will be extended to more challenging applications, substituting for analog printing technologies like silk-screen printing. The digital capability of thermal transfer will make short runs cost effective in a diverse range of analog printing applications. In particular, the printing of glass and ceramic articles is in need of such innovations. Trends toward the mass customization of such articles demand digital solutions. However, the inorganic pigments and crushed glass fluxes required in such printing applications are unlikely to be compatible with inkjet print heads. In contrast, such materials are quite amenable to incorporation in thermal transfer inks.

Inks can be formulated to cover a wide range of firing temperatures depending on substrate to be used. Pigments typically used in glass and ceramic decorating (metals, gold bearing, cadmium, colored oxides) can be easily incorporated into TTR inks. Transfer methods such as direct and indirect heat transfer as well as waterslide can be accommodated using TTR. The solid nature of TTR ribbons allows the use of some otherwise noxious pigments to be used relatively safely.

Conclusion

Thermal transfer printing has a variety of strengths and weaknesses. While it is not well suited to color office printing, it continues to dominate applied digital printing applications like auto-identification (bar code printing), shipping labels, tags and tickets. This versatile technology has advantages in speed, substrate and ink latitude and reliability over inkjet printing. Because of the separation of functions on a thermal transfer ribbon, difficult to print inkjet pigments are easily printed using thermal transfer. These attributes will enable thermal transfer printing to continue to grow and serve a wide variety of commercial and industrial digital printing applications.

Biography

Daniel J. Harrison, Vice President, Research and Development IIMAK.

Dan joined IIMAK in May, 1998. Prior to joining IIMAK, Dan was employed for 16 years at Eastman Kodak and most recently held the position of Manager, Thermal Print Media Research and Development. Dan is an inventor on over 80 world wide patents in the Digital Printing field. He holds a B.S. in Chemistry and a Ph.D. in Polymer Science from the University of Connecticut and an MBA from the Simon School of Business, University of Rochester. Dan is a member of the American Chemical Society, The Society for Imaging Science and Technology, the Society for Coating Technologies and the Association for Color Thermal Transfer.