The Role of Digital Printing and Color Technology in the Digital Revolution for the Textile World

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ABSTRACT

The digital revolution in the textile world has already started in a globalized manner in digital design and digital sampling, digital production and digital commerce underpinned by digital technology. This paper addresses on the present status of the digital printing technology underpinned by the digital color technology and its impact to the digital revolution process in the textile world.

Keywords: Textile, market trend, digital printing, analog printing, color technology, future prospect

1. INTRODUCTION

It has been a market trend for the last decade that the product cycle lifetime has shorten continuously and this trend is expected to accelerate in the next decade. In particular, it is a heavy financial burden to keep inventory whether it is parts or finished products. To minimize such difficulty and to cope with demand for new product designs frequency, the manufacturers are faced with smaller and smaller lot size for each design. These market trends will require a much higher efficient and accurate business and production information flow along the textile supply chain to enable super quick response to the market, globalized transactions, as well as to support customized and un-conventional shopping. On top of all these challenges, the world is also demanding for an environmental conscious and energy efficient manufacturing practice. The traditional analog printing technology, including screen printing and roller printing is developed to carry out mass production with abundant capacity. It consumes significant resources in pre-process and in-process preparation prior to production printing. This includes pre-process fabric preparation, colorant formulation, screen engraving and in-process fine tuning for color and engraving appearance for the print results. In particular, the screen engraving process is costly and time consuming that contributes to the major print process bottle-neck. In recent years, the use of computer aided design system, computer colorant formulation system, digital color and image communication as well as colorant dispensing system have helped to streamline the pre-production process. Nevertheless, the analog printing technology is essentially a mechanical process that creates a "mechanical gap" in the entire digital information highway along the textile complex. This has rendered the textile printers to be in a much inferior position to react to the various market challenges. In addition, the analog printing technology has the following limitations.

- Large space utilization for production machines and for screen inventory
- High consumption of water and energy
- Design limitations in terms of repeat size, design colors, and design resolution
- Difficult to realize the "print on demand" concept to minimize inventory and to produce short lot size economically
- Costly process to treat waste colorants and chemicals

2. DIGITAL PRINTING TECHNOLOGY

Advances in digital printing technology from ink jet printing to electrophotographic printing has been tremendous over the last decade and the details on this subject is widely published[1,2]. For textile industry, due to the physical and chemical nature of the substrate, ink jet printing is an important digital printing technology adopted by the industry. Most developments are based on either drop-on-demand type or continuous ink jet type. Of the drop-on-demand type, digital printing systems have been built using the piezo inkjet head technology or the thermal inkjet head technology. However, such technology development must be synchronized with both ink and media development as a pre-requisite for success.

Digital printing for the textile industry differs from conventional analog printing technology in which the digitally printed substrate is produced directly from the information system with a digitally controlled printing engine. In this aspect, the key digital information fed to the print engine is design image with colorimetric data. Thus, this offers the

option of variable information printing to support mass customization. A few suppliers have already incorporated the digital printing system as a module of the entire integrated sampling system to combine cut/print/sew in one location for fashion products to add value in time to market. In addition, the information driven system offers the advantage of print-on-demand at flexible lot size. More importantly, these features allow the open digital linkage with the external manufacturing and business digital pipeline along the textile complex. The rapidly developing information networks and digitized manufacturing processes will no doubt revolutionize the textile business implementation. As a consequence, the new opportunity offers by the digital printing technology is pretty much limited by the individual company's imagination, knowledge level, business strategy and its commitment. While digital printing technology provides an opportunity to eliminate or minimize the various difficulties associated with analog digital printing technology, it offers another interesting opportunity to complement with conventional printing in the area of sampling. Sampling or table-strike-off is an expensive process for both the customers and the manufacturers as either party normally makes no or little profit at this stage while a lot of resources have to be invested in both the engraving and color development as well as other materials preparation. At the same time, the table-strike-off activity is very intensive immediately before any major trade show, as it is customary for most converters to delay such process as much as possible. This results in major bottleneck with the conventional table-strike-off process. The screen-less print-on-demand flexible lot size digital printing technology offers a tremendous opportunity here. In short, digital printing technology offers a revolutionary role in creating new products, new services, new digital business chain as well as providing an opportunity in complementing the conventional technology in sampling and short-run

3. CHALLENGES FOR DIGITAL PRINTING TECHNOLOGY

While digital printing technology is a fairly mature technology for the paper printing industry, yet such developed technology cannot be treated as a direct drop-in technology for the textile printing industry because of the differences in physical and chemical nature of the media as well as the process variations. Nevertheless, this has presented a number of challenges as listed in the following.

System Design: Variations from paper printing in colorant volume loading, spot colors versus process colors, substrate texture, substrate flexibility, and substrate chemical nature requires careful system design and balance for various system parameters such as ink viscosity, gray levels, drop size, drop frequency, number of print heads, data communication that will impact on the resulting print speed and print resolution.

Color Reproduction: This is a major challenge for both the paper printing and the textile printing processes due to imperfect solutions or improper execution in color calibration, color profiling, color gamut matching, color instrumentation and measurements. In particular, it is more severe with textile printing if digital printing technology is employed to substitute the table-strike-off process. The use of process color and inks with physical-chemical properties differ from the analog printing process will enhance the color matching difficulty.

Print Mark Reproduction: In a similar fashion with color reproduction, digital prints must simulate the engraving appearance of the analog production prints if it is adopted for the table-strike-off process. Print quality attributes in terms of dots, lines, large area including tonal gradations and print growth must have reasonable resemblance between the two processes. In this aspect, the printers and the engravers must work closely together to provide the digital printing system with the necessary knowledge about each analog print process.

Color Fastness: The physical and chemical properties of the ink must be designed to fit the substrate quality in order to achieve an acceptable level of various color fastness properties such as crocking, washing, and light fastness. In addition, the proper treatments of the fabric before and after the printing process are essential to ensure good fastness properties.

Fabric Quality & Properties: Digital printing cannot by-pass the knowledge intensive fabric pretreatment and fabric post-treatment steps especially if it is intended for production purpose. Proper pretreatment promote satisfactory print appearance while proper post-treatment allows fashionable effects and provides additional values such as improved handle, luster, color fastness or soil resist property to the fabric. On the contrary, in-consistent or poor treatment will result in color and print mark variations. These two value-add on steps also present a logistic supply issue if users do not have such facilities. In addition, any inconsistent fabric speed, fabric wrinkling, loose fibers and the touching of the ink jet nozzle will present great challenge to the print quality

result.

Ink Issues: The textile printers prefer inks to be compatible with colorants used in the analog printing process to facilitate co-ordination and to maintain similar color effects. At present, inks for digital printing are available in reactive inks for cellulose, acid inks for protein fibers, disperse inks for polyester and pigment inks for all types of fibers. However, due to the physical parameter restrictions for ink jet printing, some ink may not perform satisfactory in terms of fastness or color range requirements.

Printing Speed: In an absolute sense, the print speed of digital printing is extremely slow in comparison with the analog printing. Typical speed for rotary screen printing is up to about 60 m/min. while for digital printing is up to about 60 m/hour for drop-on-demand type printer. The speed of digital printer is restricted by various factors including the number of color heads and its nozzles, the type of ink jet technology, the capacity of data handling rate and the desired print resolution etc.. For digital printers that adopt thermal print head has an additional critical issue of limited head lifetime. However, if we consider the total picture including the time saved in screen engraving and the fact that digital printing is a more efficient, flexible and creative process, the print speed issue is less critical. On the other hand, some users are adopting a "multiple printers" concept where many digital printers are employed to carry out the production to enhance the print capacity in a way similar to a weaving operation.

Print Width: Most digital printers are designed with print width up to about 1.6m and this present a challenge to the domestics market that requires print width of about 3m.

Printing Cost: The present high cost of inks for digital printing couple with other factors such as the low machine throughput have rendered digital printing not suitable for long production run.

User Knowledge: In many instances, the users expect to purchase a digital printing system that will perform as a turn-key system and quickly experience disappointment.

4. COLOR TECHNOLOGY

As far as digital printing is concerned, one can consider the color technology as a pillar technology for digital printing. As a matter of fact, a major challenge reported for both digital and analog printing is color reproduction. The advances in both basic colorimetry and advanced colorimetry have contributed significant value to the digital printing technology. The International Commission on Illumination (CIE) basic colorimetry includes the objective specification of colors based on tristimulus values (1931) as well as the CIELAB and CIELUV systems (1976) for both color and color difference specifications. More advanced and recent color difference formula includes the CMC formula (ISO 105-J03:1995) widely adopted in the textile industry as well as the CIE94 formula that is also an ISO standard (ISO/DIS 7724 Part 6) for the paint industry. In the mean time, CIE TC1-47 is focusing on the modification of the CIELAB formula following the format of CIE94 and CMC to develop the new CIEDE2000 color difference formula. The CIE advanced colorimetry includes the color appearance model for prediction of changes in color appearance according to different viewing conditions. In 1997, the CIE adopted the CIECAM97s color appearance model. In cross media color reproduction for digital printing application, the CIE basic colorimetry is important in device characterization model as well as the provision of a device independent color space for profile connection. In addition, the International Electrotechnical Commission (IEC) TC100/TA2 is developing standard method for characterizing various input/output devices. On the other hand, the CIECAM97s is important for predicting color appearance under different viewing conditions in cross media color reproduction. Due to the variations of viewing conditions in practice, the use of spectral based device characterization could minimize metamerism. Another challenge to cross media color reproduction is the usual mis-match of color gamuts for various media, CIE TC 8-03 is developing a universally applicable gamut mapping model. The industry standards on device profile format (International Color Consortium, ICC) and the TIFF 6.0 image file format (Computer Integrated Textile Design Association, CITDA) provide an important basis for the textile industry to exchange digital files for digital printing applications. CITDA has also formed a Color Standards Committee to improve the communication and management of color for the manufacturing of soft goods, from initial design through to final product on the retail floor.

Since the fifties, color measuring instruments have evolved from large, heavy, slow measurement speed, low precision, costly and cumbersome data reduction task to portable, high speed, high precision, affordable and very user friendly. Such advancement has rendered textile retailer to communicate color quality by "numbers" as oppose to the use of "physical colors" to accelerate the time to market cycle. The success of this method requires a highly standardized method and procedure to be adopted by all partners in the complex. More recently, this method has been supplemented with digital color image communication[3] using calibrated and characterized color monitors to provide instant color communication along the entire textile supply chain providing an opportunity

for distributed digital printing operations around the world. On the other hand, it can be a challenge, in terms of reliability, repeatability and productivity, to use standalone color measuring instruments for digital printer characterization for textile application simply because of the large number of colors to be measured manually. To resolve this issue, automatic color scanning system has been developed to carry out the color profiling task automatically[4].

5. FUTURE PROSPECTS FOR DIGITAL PRINTING TECHNOLOGY

A recent market study report[5] shows the market growth potential for digital textile printing is very attractive in comparison to the other industries. Worldwide installation of digital printing systems for textile application in sampling and short run production is expected to reach a growth rate of 52% during the period 1999 to 2004. This is consistent with the market trend and demand as elaborated in sections (1) and (2) of this paper. There is great incentive for digital printing system developer to address the various technical and business challenges to satisfy the market. However, the success can only be achieved via a partnership approach technology-wise and market-wise among the print engine suppliers, the ink suppliers, the media suppliers, the CAD/color system suppliers, the information technology suppliers, the users as well as the thorough understanding of the end customers. The recent textile shows at the Heimtextil in Frankfurt, Germany (Jan. 2001) and the ATME-I in Greenville, USA (Apr. 2001) have demonstrated significant advances in addressing the various technical challenges including print speed, print width, print head height flexibility, more user friendly inks, options of spot colors, increase in print head colors, in-line printed fabric finishing and the use of conventional roll to roll flat-bed table top for smooth transportation of fabric.

Both the rapid market development and the rapid technology development will have great impact to the textile industry in the foreseeable future. The textile printing industry will become a knowledge intensive manufacturing operation that will require a much higher education level production personnel to operate the future textile plant. Here, the textile colleges, the government and the textile industry must play an active role to invest in technical education. The recent announcement of the Philadelphia University in building a Center of Excellence in Digital Ink Jet Printing at the School of Textiles and Materials Technology is an exciting development. It is the people's knowledge that will render success or failure in the new Millennium. The advances in digital infrastructure and the digital printing system will allow globalized product development and production. Companies can determine the most effective domestic-offshore manufacturing mix to determine the quickest response to the market and generate the best financial reward. Mass production textile print centers will be more demanding for quality as oppose to quantity and its locations will shift to the developing countries particularly in places where the growth in consumers is significant. There will be numerous one-stop imaging, color and textile print servicing centers around the world with major focus in mass customization flourishing initially in developing countries and then spreading elsewhere. The future textile printing industry is exciting. Are you ready?

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