A Study on Colour Print Quality Attributes Variance of OMR between PET and ABS by Digital Inkjet Printing

Xiaoling Lu\textsuperscript{1,*} and Changlang Chen\textsuperscript{2}

\textsuperscript{1}Art and Design College of Jiangsu University of Technology, China
\textsuperscript{2}Department of Graphic Communication Arts, National Taiwan University of Arts, Taiwan

*Corresponding author email: 2002500042@jstu.edu.cn

Abstract. In-mould transfer printings are limited, such as surface bending, only on plastic parts, cost higher and print for a small run length of productions. OMR transfer can be transferred to plastic or metal, transfer process accurate register, high quality and tolerance. The current printing market tend to develop personalized, so this study to use digital inkjet printing, through rigorous experimental process and quantitative measurement and comprehensive analysis, summarized the most suitable digital inkjet printing methods and the best quality attributes. In each combination, the samples will be selected to transfer printed products which will be examined for print quality attributes (SID, TVI, PC, colour difference and colour gamut). This study results found that when the higher coverage and the lower pass of inkjet printing, the SIDs will become higher as well. When transferred to ABS, SIDs in each combination will increase. The higher coverage printed, the higher TVI. After transferred into ABS, each combination of PC is worst. When transferred to ABS, colour variances of each combination are different from orange and cyan colour. Through this study, we can get the colour correspondence between the original and the finished product ABS, to establish the personalized service process, to improve the digital inkjet printing and technology application to enhance its product added value, and to provide research results to give back to the printing market. It can bring new opportunities for the industry.

1. Introduction
With the advancement of society (especially the rapid development of 3C and the automotive decoration industry), the use and function of plastics are becoming more diversified, consumers are constantly demanding the pattern and texture of the surface of the products, and various production technologies and equipment are changing with each passing day. Under the pressure of survival competition, the production technology, cost and production cycle are facing serious challenges, such as improving product quality, reducing defective products, reducing processing, assembly time and cost. The printing method that can print the most texture and the best effect on irregular objects has been widely used in industrial production. It can make up for the lack of in mould roller (IMR) production process. Due to the wide application field of the Outside mould (OMD) transfer technology, the process stable is better than the water transfer printing, the beautiful appearance of the product, and the good economic benefits, it has gradually been favored by many manufacturers.

OMR is now using Gravure and Screen Printing to print Polyethylene terephthalate (PET) film, however, there are still some problems with these two technologies. For example, the process of Gravure Printing is more complex and expensive. Screen Printing is cheaper but the process is also complex. These two kinds of printings are both unable to create personalized work, while Digital Inkjet Printing can.
Therefore, this research is to investigate the potential use of combining OMR and Inkjet Printer in 3D decoration. Digital Inkjet Printing can print precision colour products without the need for platemaking, compatibility, ease of operation [1]. It is the trend of the printing [2]. This research is mainly to expand the application of the results of the in mould transfer, through the digital inkjet printing combined with the process of the mould transfer, the process is standardized, and the literature analysis and quantitative experiments are supported to derive the best. It’s bringing about the advancement of digital inkjet printing and mould transfer technology, the improvement of printing quality and customer satisfaction.

2. Literature

2.1. Digital UV Inkjet Printing
Digital Printing uses digital technology to personalize various documents and materials, and uses the prepress system to transmit various types of graphic information directly to the digital printing machine through the network, and prints a printing of the product. The computer uses the digital format to print the information of the archived content on the printed material. Digital printing is mainly referred to as Non-impact printing (NIP) [3]. Its turnover has gradually increased and it has become a printing in recent years. It’s the new trends in the media.

Digital UV printing is a very potential printing method. It is widely used for printing. UV-dried inks can be used in a wide variety of different printed materials. This ink enables faster production because it is polymerized using ultraviolet light for instant drying. It is different from traditional ink structures and is mainly used for the printing of non-absorbent substrates, such as plastic and metal sheets. At present, with the advancement of technology, LED-UV light sources have been successively adopted.

2.2. Type of Transfer Printing
In printing technology applications, transfer printing technology, such as non-planar products, special materials, is required. This study is one of transfer printing. Transfer printing decoration technologies had including thermal transfer printing, water transfer printing, in mould roller /reprint (IMR) / outside mould roller (OMR), in mould label (IML), in mould film/forming (IMF) [4].

2.3. Print Quality Attributes
The print quality attributes are a general term for quantitative analysis of images, and may include colour print quality attributes and physical print quality attributes. Physical print quality attributes are physical testing of products such as weather resistance, water resistance, wear resistance…etc. Colour print quality attributes are print colour testing of products such as solid ink density(SID) of cyan(C), magenta(M), yellow(Y) and black(K), tone value increase (TVI), print contrast (PC), colour difference (E), colour gamut, etc. [5].

3. Research Methods
In this study, the True Experimental Method was used to investigate the suitability of the digital inkjet printing process for the combination of OMD printing. After the inkjet printing of the PET transfer film, the printed colour quality attributes exhibited by the OMD transfer to the printed material -Acrylonitrile butadiene styrene (ABS) are transferred. Digital inkjet equipment adopts Mimaky's roll to roll flat-bed UV inkjet, which is one of the main equipment that can simulate the beautiful quality of printing [6]. The experiment is to continue the optimum combination mode of the film coating release agent and the hardened layer, using two resolutions (720 dpi, 1440 dpi), three kinds of printing passes (8 pass, 16 pass, 32 pass), two kinds Ink coverages (100%, 120%) combination, in addition to analysing the colour quality attributes exhibited after inkjet printing, and examining the printing colour quality performance and physical attributes test. They are 12 experimental combinations from A to L, such as A (720dpi, 8pass, 100coverage), B (720dpi, 8pass, 120coverage), G (1440dpi, 8pass, 100coverage), L (1440dpi, 32pass, 120coverage) …etc.

4. Research Results and Discussion
The experimental results obtained are shown and discussed below.
4.1. Solid Ink Density (SID)
Density is the ability of the printed material to absorb light, and SID refers to the highest density of colour printed on the printed material. This study refers to the highest density of each colour of the printed PET after different inkjet printing conditions and after transfer to ABS. As shown in Figure 1 and 2, the coverage is high, and the SID is relatively high, in the case of low coverage, SID after transfer is generally higher than that before. After the ink is high temperature, it is easy to carbonize and blacken, causing the SID to rise, but when the coverage is increased, it is not significant.

![Figure 1](image1.png)

**Figure 1.** The SID of different printing pass (8.16.32), same resolution (720) and coverage 100% (ACE) (left) and different printing pass (8.16.32), same resolution (720) and coverage 120% (BDF) (right).

![Figure 2](image2.png)

**Figure 2.** The SID of different printing pass (8.16.32), same resolution (1440) and coverage 100% (GJK) (left) and different printing pass (8.16.32), same resolution (1440) and coverage 120% (HJL) (right).

4.2. Tone Value (TV) and Tone Value Increase (TVI)
Before transfer (PET) and after transfer (ABS), the reproduction curve is adjusted by A (720dpi, 8pass, 100coverage) and G (1440dpi, 8pass, 100coverage). After the transfer is completed, the dot area is increased in the highlight area, But the middle to shadow tone area are not significant, as shown in Figure 3 and 4.
4.3. Print Contrast (PC)

Before (PET) and after (ABS) printing comparison of the experimental combination A (720dpi, 8pass, 100coverage) and G (1440dpi, 8pass, 100coverage) after the transfer, the PC is lower than before, the high temperature transfer leads to the shadow area. The level is getting worse. In this study, a comparison of the 75% dot area was used for comparative analysis. The larger the PC, the richer the tone, as shown in Figure 5.

![Figure 5. Pre-transfer (PET) versus post-transfer (ABS) comparison print contrast (PC) values.](image)

Figure 3. Comparison A & G of the reproduction curve before and after transfer.

Figure 4. Relative percentage tone value increase (TVI) of dots after transfer.
4.4. Colour Gamut Analysis
Based on the Lab colour space, the colour gamut of each experimental combination before and after the transfer are depicted. As shown in Figure 6, after the OMD transfer to the ABS material, the brightness value (L) of all products decreased. After the transfer, the ink is slightly burnt, in the colour and colour domain, it can be known that the first and third quadrants change greatly after the transfer.

![Figure 6. Comparison of pre-transfer and post-transfer colour gamut.](image)

4.5. Colour Difference(ΔE)
Comparing the colour difference between the pre-transfer (PET) and post-transfer (ABS) colours, the colour difference ΔE of the K colour is below 1-3.2, and the C colour is 6-15, the M colour is 5-11 and the Y colour is 1-7. The K colour has better consistency in colour performance, and the Y colour and the M colour are the second, and the C colour is inferior. It should be that the high temperature in the transfer process has a great influence on the ink of the Cyan colour.

4.6. Dot Characteristics Reproduction Curve
As shown in Figure 7, the dot characteristics reproduction curve of the different combinations (A (720dpi, 8pass, 100coverage) and H (1440dpi, 8pass, 120coverage)) are related to the calibration curve, and the first quadrant of the figure is the reproduction curve between the original and the finished product (ABS), the second quadrant is the curve of PET before transfer to after the transfer ABS, the third quadrant is PET 45° corresponding straight line, the fourth quadrant is the curve of original to PET, from this figure can be obtained from the original to the finished product ABS between the dot change.

![Figure 7. The dot characteristics reproduction curve of A (left) and H (right).](image)
5. Conclusion
Following conclusions are found in this study below.

- When the coverage is low, the SID is higher than that before the transfer.
- After the transfer, the dot area is increased in the highlight, which makes the tone reproducibility better.
- The experimental combination of A (720dpi, 8pass, 100coverage) and G (1440dpi, 8pass, 100coverage) after transfer, the maximum TVI of each colour occurs in the highlight area.
- All experimental combinations after the transfer, the PC is lower than before the transfer.
- After the OMD transfer to the ABS material, the brightness value (L) decreased, mainly due to carbonization and charring after transfer. It can be known that the change of orange and cyan after transfer is significant.
- Comparison of colour difference ($\Delta E$) before and after transfer: K colour has better consistency in colour performance before and after transfer, Y colour and M colour second, C colour is poor. It should be that the high temperature in the transfer process has a great influence on the ink of the Cyan.
- Through the integration before and after the transfer, the correspondence of the dots presented from the original to PET to ABS product can be obtained. This allows us to understand the changes in the dot area between the original electronic file and the finished product ABS. It can control the colour at production process.

References
[1] Chen C L and Lo M C and Su Y T and Chang Y T 2012 The study on colour print quality attributes of In-Mold Roller using digital inkjet printing Applied Mechanics and Materials Vol 262 pp 340-344
[2] Chen C L 2020 A Study on tone reproduction integration curves of injection moulding using digital transfer printing Chinese Association Graphics Science and Technology Journal Chinese Association Graphics Science and Technology Taiwan pp 3-12
[3] Kipphan Helmut Ed 2001 Handbook of Print Media Berlin Germany Springer pp677-687
[4] Chen C L and Chang Y T and Taso S H and Hsu W C 2014 The study on colour quality attributes of IMR with PET on white ink by UV inkjet Advanced Materials Research Vols 1004-1005 pp799-802
[5] Chen C L and Wang Y L 2009 The study on colour print quality attributes of Water Transfer by Digital Printing Chinese Association Graphics Science and Technology Journal Chinese Association Graphics Science and Technology Taiwan pp 169-190
[6] Lo M C and Chen C L and Perng R K and Hsieh T H 2006 The Characterisation of Colour Printing Devices via Physical, Numerical and LUT Models, CGIV 2006 IS&T’s Third European Conference on Colour in Graphics Imaging and Vision University of Leeds UK pp 95-99