Journal of Harbin Engineering University
ISSN: 1006-7043

Vol 46 No. 7
July 2025

Quantitative Analysis of Color Shift Induced by Diverse Coating Techniques on Offset-Printed Coated Media

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Abstract

This research examines the color shift effects induced by various aqueous coatings—Gloss, Matt, and Neutral—on offset-printed coated media. Precise color reproduction is essential in the printing industry, where even minor deviations can affect print quality. Offset printing on coated paper provides high-quality output; however, post-printing coatings often cause shifts in colorimetric values, altering the appearance of printed colors. This study investigates the impact of these coatings on color shift, measured as ΔE, across four process colors (Cyan, Magenta, Yellow, and Black) and three types of coated media (C1S, Gloss Art, and Matt Art paper).

The findings reveal that Aqueous Gloss coating effectively stabilizes color, especially for Cyan and Black on C1S and Matt Art papers, showing reduced ΔE values and consistency, although it slightly increases shifts for Magenta and Yellow, notably on Gloss Art Paper. In contrast, Aqueous Matt coating generally increases ΔE across all colors and papers, causing the highest variability, particularly in Magenta and Yellow, making it less suitable for applications demanding minimal color shift. Aqueous Neutral coating provides a balanced effect, reducing ΔE values for Black and Yellow on Matt Art Paper while maintaining moderate color shifts for other colors. This balance offers a viable option where controlled color retention is needed, particularly for applications on Matt Art Paper.

In conclusion, Aqueous Gloss and Aqueous Neutral coatings are recommended for applications requiring color stability, with Aqueous Gloss excelling in Cyan and Black retention. Aqueous Matt coating induces higher color shifts, rendering it less effective for preserving original color fidelity. These findings highlight how coating choice can optimize color consistency in offset printing, allowing tailored applications based on substrate and desired color retention.

Keywords: Colorimetric analysis, visual consistency, aqueous polymer emulsion, ΔE color measurement, print color fidelity, substrate interaction, spectral reflectance, post-press coatings, gloss variability, hue stability, polymer emulsion coatings, optical density, surface smoothness, CIE Lab* color model, ink holdout

1. Introduction

In the printing industry, achieving accurate color reproduction is essential for preserving the quality and visual appeal of printed materials. This becomes particularly critical in products such as illustrated books, magazines, marketing materials, and high-end packaging, where precise color matching is key to maintaining brand integrity and visual consistency (Anayath & Pandey, 2015). Offset printing, known for producing sharp, high-resolution images, is widely used on coated media—a preferred substrate for vibrant colors and detailed imagery (Koivula, Preston, Heard, & Toivakka, 2008). This technique's indirect ink transfer method minimizes image distortion, enhancing color accuracy. However, post-printing processes, especially the application of protective coatings, often introduce undesired color shifts. These shifts, measured by the ΔE value in the CIE Lab* color model, can alter intended colors, leading to inconsistencies in final output (Baumann & Timpe, 1994).

Coated media, including gloss, matte, and C1S (coated one side) papers, are commonly used to optimize image quality by enhancing surface smoothness, brightness, and ink retention. The non-porous surface of coated media prevents ink absorption, resulting in sharper images and more vibrant colors compared to uncoated alternatives. However, when aqueous coatings—typically gloss, matte, or neutral—are applied to improve durability and appearance, they interact with printed ink in ways that affect color perception. Gloss coatings tend to amplify color vibrancy through high reflectivity, while matte coatings, by diffusing light, create a more subdued color effect.

Previous research highlights how different coatings affect color shifts, with findings indicating that gloss and matte finishes distinctly influence colorimetric values (Maeda, et al., 2005). Gloss coatings can stabilize colors like cyan and black, while matte coatings are prone to variations in colors such as yellow and magenta due to their unique light-diffusing properties (Bhagya & Pai, 2017). Although several studies have examined these effects, few have comprehensively compared the color shift across different coated papers (C1S, gloss art, and matte art) when exposed to the three main coating types—aqueous gloss, matte, and neutral (Haniyu, et al., 2003).

This study aims to fill this gap by evaluating how these aqueous coatings impact color stability across different paper types and process colors (cyan, magenta, yellow, and black) in offset printing. It seeks to identify which coating techniques offer the most consistent color retention for each color-paper combination, with the goal of minimizing undesirable color shifts that may compromise print quality. By addressing the role of specific coating methods in maintaining color fidelity, this research offers critical insights for printers, designers, and other stakeholders in selecting appropriate coatings to meet quality and aesthetic requirements.

By systematically analyzing color shifts induced by various coating techniques on different coated media, this study provides valuable guidance on optimizing coating selection to achieve color stability in offset printing applications.

This study provides valuable guidance on optimizing coating selection to achieve color stability in offset printing applications. To understand the intricacies of this process, we will now explore the offset printing technique, its role in achieving precise color reproduction, the characteristics and advantages of different types of coated media, and the impact of various aqueous coating techniques. This foundation will set the stage for analyzing how these elements interact to influence color fidelity and print quality.

Offset Printing

Offset printing is an indirect method of printing which underlies on the principle 'Oil and Water do not mix with each other'. During printing image area is ink-accepting and non-image area water-receptive. Ink is applied on image area by inking unit and dampening solution is applied on image carrier by dampening unit. Then inked image in transferred on the blanket (rubber) cylinder which is further on to the substrate using suitable impression pressure by impression cylinder. Fig. 1 depicts working principle of Offset printing.

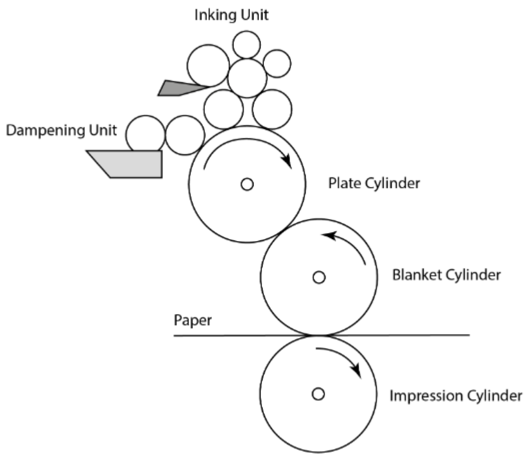

Fig. 1. Offset Printing Principle

Colour accuracy and consistency are critical in the printing industry, where even slight deviations can impact the quality and marketability of printed materials. Colour accuracy is a critical performance specification of a printing device which is need of hour these days. But finishing operations which includes varnishing, coating and lamination can significantly alter the print appearance.

Colour shift is the colour difference commonly evaluated in terms of delta E (ΔE) using CIE L*a*b* Colour model. CIE L*a*b* colour space is composed of three dimensions which includes L* (Lightness/Darkness), a* (Green-Red axis) and b* (Blue-Yellow axis) (Lundström, 2013).

Lamination is a post-press finishing technique commonly used to protect any printed materials. In addition to this it enhances the aesthetic appeal of printed material. It also increases not only durability, but also the resistance of print media to various environmental aspects. Despite of so many advantages, lamination causes colour shift of printed media in terms of visual perceptions (Kipphan & Loffler, 1989).

Coated Media

Coated media, including coated paper and board, is widely used in offset printing to achieve high-quality, vibrant prints with excellent colour reproduction. Coated media is treated with a layer of coating—usually a mix of clay, calcium carbonate, and binders—that smoothens the surface, enhances brightness, and improves ink holdout. This coating allows for finer image detail, making it ideal for applications like magazines, brochures, packaging, and high-end marketing materials.

Composition and Interaction with Offset Inks

Coated media is typically composed of a paper or board base coated with a layer of minerals and polymers. This coating provides a smooth, non-porous surface, which interacts differently with **oil-based offset inks** than uncoated paper. Unlike uncoated paper, which absorbs ink, coated paper holds the ink on the surface, enabling sharper images and less ink absorption. This feature requires specific drying processes, as the ink must dry through **oxidation** and **evaporation** rather than absorption. In offset printing on coated media, the ink dries primarily through a combination of **oxidative drying** (reaction with oxygen) and **infrared or hot-air drying** to speed up evaporation. This controlled drying process ensures a smooth, glossy, or matt finish, depending on the media type (Tetsuya & Yosuke, 1998).

Types of Coated Media

SBS C1S (Solid Bleached Sulfate, Coated One Side) Art card/Paper

Chemical Properties

- **Composition**: SBS (Solid Bleached Sulfate) paperboard is made from 100% bleached virgin wood pulp, which gives it a bright, white base. The paperboard is coated on one side (C1S) with a layer of clay and/or calcium carbonate and a binder, usually a polymer such as styrene-butadiene or polyvinyl acetate.
- **pH Neutrality**: The use of bleached pulp makes SBS paperboard more pH neutral and resistant to yellowing over time, which is ideal for archival-quality prints and long-term storage.

Physical Properties

- **Brightness and Whiteness**: SBS C1S has a high brightness level, typically above 90 on the ISO scale, which enhances the vibrancy of printed colours.
- **Rigidity and Strength**: SBS C1S is known for its stiffness, rigidity, and good folding endurance. This structural strength makes it suitable for applications where durability and structural integrity are required.
- **Surface Smoothness**: The coated side provides a smooth, even surface that ensures excellent print quality, allowing for sharp images and vibrant colours.
- **Weight and Thickness**: SBS C1S is available in various weights (200 to 450 gsm) and thicknesses, making it adaptable for different applications, from thin card stock to thicker boards for book covers and packaging.

Gloss Art Paper

Chemical Properties

- **Composition**: Gloss art paper is typically made from a combination of wood pulp fibers and mineral coatings. The coating is often a mixture of clay, calcium carbonate, and other minerals, with a binder like polyvinyl acetate or styrene-butadiene. The binder secures the coating to the paper and contributes to a glossy finish.
- **Optical Brighteners**: Gloss art papers often contain optical brightening agents (OBAs) to enhance the whiteness and brightness of the paper, allowing colours to appear more vibrant.
- **pH Levels**: Gloss art papers are usually pH neutral or slightly alkaline, which helps maintain colour quality over time and prevents yellowing.

Physical Properties

- **High Reflectivity**: The glossy coating provides a highly reflective surface, which makes colours appear more saturated and vivid. This characteristic is beneficial for applications that require bright, eye-catching visuals.
- **Smoothness and Ink Holdout**: Gloss art paper has an exceptionally smooth, non-porous surface, which prevents ink from absorbing deeply into the paper. This feature ensures sharp detail and prevents ink bleed, resulting in high-resolution prints.
- **Brightness**: Gloss papers have a high brightness level, often over 90 on the ISO scale, which enhances the colour contrast and sharpness of images.
- **Weight and Thickness**: Gloss art paper is available in various weights (90 to 190 gsm) and thicknesses, making it suitable for different printing needs, from lightweight brochures, illustrated books, book jackets, multicolour books to heavyweight magazine covers.

Matt Art Paper

Chemical Properties

- **Composition**: Matt art paper is similar to gloss art paper in terms of its base material, with wood pulp fibers and mineral coatings. However, it has a different coating formulation that scatters light rather than reflecting it directly, resulting in a matt finish.
- **Binders and Additives**: The coating for matt art paper includes similar binders, such as polyvinyl acetate or styrene-butadiene, but may have additional matting agents or texturizers to reduce glossiness.
- **Absence of Optical Brighteners**: Some matt papers do not contain optical brighteners, which gives them a softer, more natural tone and reduces the starkness of colours.

Physical Properties

- **Low Reflectivity**: The matt coating diffuses light, resulting in a non-reflective surface that reduces glare. This property is advantageous for applications where readability is important, as it prevents reflections from affecting legibility.
- **Smooth but Less Glossy**: While still smooth, matt art paper lacks the high reflectivity of gloss paper. It provides an elegant, refined look that is more subdued and professional, suitable for materials that require a sophisticated appearance.
- **Brightness**: Matt art paper typically has a high brightness level, although it may appear less vibrant than gloss paper due to its non-reflective surface. This feature is desirable for applications where a subtle finish is preferred.
- **Ink Absorption and Image Quality**: Although matt paper is smooth, it absorbs slightly more ink than gloss paper, resulting in softer colours and a slightly less sharp finish. However, this is often preferred for fine art prints and luxury print materials where a muted, classic look is desired.
- **Weight and Thickness**: Matt art paper is available in various weights (90 to 190 gsm) and thicknesses, making it suitable for different printing needs, from lightweight brochures, illustrated books, book jackets, multicolour books to heavyweight magazine covers.

Table 1: Comparison Chart of Various Coated Media

Property	SBS C1S Art card/Paper	Gloss Art Paper	Matt Art Paper
Composition	100% bleached virgin wood pulp with one-side coating	Wood pulp with glossy mineral coating	Wood pulp with matt mineral coating
Binders	Styrene-butadiene or polyvinyl acetate	Polyvinyl acetate, styrene-butadiene	Polyvinyl acetate, styrene-butadiene
Reflectivity	Moderate	High (Glossy, reflective surface)	Low (Non-reflective, matt finish)
Brightness	High (Above 90 ISO)	High (Enhanced by optical brighteners)	High, but with a softer, non-glossy appearance
Surface	Smooth, coated on one side	Smooth and very glossy	Smooth but non-glossy
Strength	High rigidity and stiffness	Moderate flexibility	Moderate flexibility
Ink Holdout	High, minimal absorption	High, sharp details due to low ink absorption	Moderate, slightly softer due to light absorption

Coating

Aqueous coating is a water-based protective coating widely applied on printed papers and boards to enhance durability, appearance, and resistance to wear. Used extensively in packaging, brochures, book covers, and other printed materials, aqueous coatings are popular for their eco-friendly properties and low VOCs (volatile organic compounds). This coating provides a quick-drying and versatile solution with options for different finishes—matt, gloss, and neutral—depending on the desired aesthetic and functional outcome.

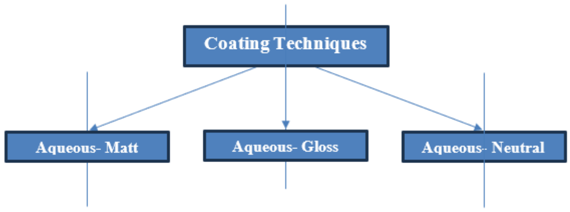

Fig. 2. Coating Techniques

Process

The aqueous coating process relies on a series of **physical drying and coalescence interactions** rather than traditional chemical reactions. Water evaporation and polymer coalescence form a continuous, protective film over the printed surface, while optional crosslinking may provide additional chemical stabilization. This process, enhanced by controlled drying conditions, creates a durable finish that enhances appearance and protects the printed material (Breiner, Klesse, Schmitt, Schütz, & Urbanek, 2011).

Application of Aqueous Coating

- The aqueous coating is applied to the printed surface using rollers or flexographic coaters in the offset printing process.
- This coating is a water-based emulsion consisting of water (as the main solvent), polymer particles (often acrylic or styrene-acrylic), and other additives (e.g., wax, surfactants, defoamers).
- The coating is spread evenly across the surface of the paper, covering the printed inks without dissolving or disturbing them.

Evaporation and Drying Process (Irfan, Ahmed, Kolter, Bodmeier, & Dashevskiy, 2017)

- The coating undergoes drying primarily through the evaporation of water, which is facilitated by infrared (IR) dryers or hot-air dryers.
- As water evaporates from the coating, the concentration of polymer particles in the remaining solution increases.
- This reduction in water volume brings the polymer particles closer together.

Polymer Coalescence

- As the water content decreases, the polymer particles begin to coalesce, or fuse together, due to van der Waals forces and capillary forces.
- During this stage, polymer particles deform slightly as they come into close contact, forming a continuous layer.
- The surface tension of the remaining water and any surfactants in the mixture helps facilitate the particles' movement and merging, allowing them to coalesce into a single, continuous film.

Film Formation

- As coalescence progresses, the individual polymer particles merge completely, creating a smooth, continuous film across the coated surface.
- The film solidifies as the last traces of water evaporate, resulting in a durable protective layer.
- Additives like wax particles, if included in the coating formulation, are distributed throughout the film and add properties like abrasion resistance and smoothness.

Crosslinking and Chemical Stabilization

- Some advanced aqueous coatings may contain **crosslinking agents** that can initiate mild chemical bonding between polymer chains, leading to **chemical stabilization**.
- This crosslinking may be triggered by the heat from the drying process and contributes to the **durability and hardness** of the coating. However, not all aqueous coatings use crosslinkers, as the primary mechanism is still physical film formation.

Adhesion and Interaction with Offset Ink

- **Ink Compatibility**: Offset inks are often oil-based or UV-cured. Aqueous coatings are formulated to avoid rewetting or disturbing these inks, adhering instead to the ink surface.
- **Adhesion Mechanisms**: Adhesion is achieved through **van der Waals forces** and **hydrophobic interactions** between the coating polymers and the printed ink layer. This ensures that the aqueous coating adheres effectively, providing a protective barrier.

Details of Aqueous Coating

- **Usage and Need**: Aqueous coatings provide a protective layer that enhances resistance to fingerprints, smudges, and abrasions, increasing the product’s longevity and appeal. This coating is also selected for its eco-friendly profile, as it uses water as the primary solvent.

- **Chemical Composition**: The coating is typically based on acrylic or styrene-acrylic polymer emulsions, which form a durable film when dried. Additives may include wax for abrasion resistance, matting agents for a matt finish, or gloss enhancers (Menzel & Nickel, 1992).
- **Application Process**: The coating is applied over printed material using roller or flexographic coating units and dries through evaporation, often accelerated with infrared or hot-air dryers.
- **Thickness**: The applied layer is usually between 1-3 microns thick, providing an effective protective layer without adding bulk.

Factors Affecting Effectiveness

- **Temperature**: Higher temperatures promote faster drying and can prevent unevenness but require careful monitoring to avoid overheating.
- **Pressure**: Adjusting pressure is essential for achieving a uniform coating layer; excessive pressure can create an uneven texture or thin out the layer.
- **Humidity**: High humidity slows down drying and may cause streaking or haziness in the finish.
- **pH Levels**: Maintaining the proper pH in the aqueous solution is essential to prevent coagulation of the polymers, ensuring a smooth and consistent film.
- **Machine Settings**: Roller speed, pressure, and coating volume settings must be calibrated precisely for even application, as any misalignment can affect the coating quality.

Table 2: Comparison Chart of various Aqueous coatings

	Aqueous Matt	**Aqueous Gloss**	**Aqueous Neutral**
Appearance	Non-reflective, smooth finish	High shine, reflective	Subtle, clear, nearly invisible
Usage	High-end brochures, luxury items	Retail packaging, marketing materials	Functional protection without shine
Chemical Additives	Matting agents to diffuse light	Gloss enhancers for shine	Clear acrylic with minimal additives
Application Process	Standard roller or flexo coat	Standard roller or flexo coat	Standard roller or flexo coat
Thickness	1-3 microns	1-3 microns	1-2 microns
Sensitivity to Humidity	Moderate	High	Low
Final Finish	Soft, understated aesthetic	Vibrant, eye-catching	Neutral, minimal impact on look

2. Objectives of Study

Print enhancement is very crucial aspect for attractive and innovative print applications for which numerous post printing coatings are made on printed substrates are used for enhancing print quality now-a-days. But every coating technique has its unique effect on print enhancement in terms of colour shift or print quality parameter. The key objective of this study is to analyze the phenomenon of colour shift due to various aqueous polymer emulsion coating techniques on Coated Paper media printed using offset printing.

3. Research Methodology

For carrying out the study of Colour Shift effect of various Coating Techniques on Coated Media post Offset Printing, first and foremost a Master Test Chart was developed by incorporating technical parameter as per printing standard. The flowchart for executing the research process is as below:

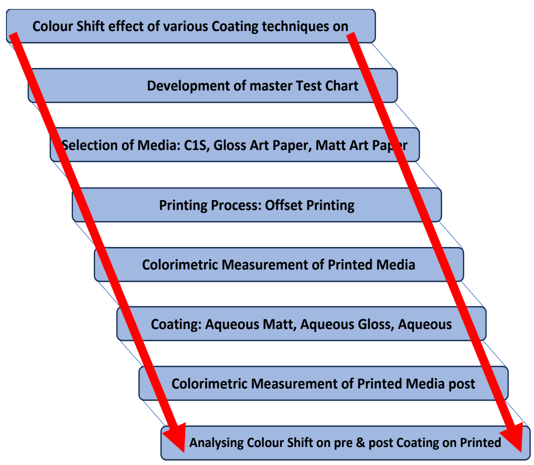

Fig. 3. Flowchart for attainment of research objective

i. Master Test chart: Suitable master test chart was developed by incorporating various elements keeping in view of research objective

ii. Media Selection: Three coated paper medias, Solid Bleached Sulfate Coated One Side art card, Gloss Art Paper and Matt art paper were taken into consideration for research work.

iii. Process of Printing: Offset printing process was used for printing for this study under standard press room condition.

iv. Colorimetric Measurement: Colorimetric data of Printed sheets (before Coating) were captured using a spectrophotometer for selected printed samples (Verikas, Bacauskiene, & Nilsson, 2007).

v. Coating Process: Three coating processes, Aqueous Matt, Aqueous Gloss and Aqueous Neutral were carried out on selected samples for which pre-Coating colorimetric data was captured.

4. Data Analysis

In order to analyze colour shift effect of various coating techniques (fig. 2) on Coated Media using Offset Printing process, colorimetric aspect colour difference (ΔE Value) was taken into consideration (Södergård, Launonen, & Äikäs, 1996). The analysis of data (number of sample sheets measured on X-axis and their respective colorimetric value i.e. ΔE Value on Y-axis) is depicted as below:

1. **Colour Shift Due to Aqueous Coatings (Gloss, Matt, Neutral) on C1S Paper:** The colour shift (ΔE Value) of process colours—Cyan, Magenta, Yellow, and Black—during offset printing on C1S coated paper with Gloss, Matt, and Neutral aqueous coatings is shown in Fig. 4, 5, 6 and 7 respectively).

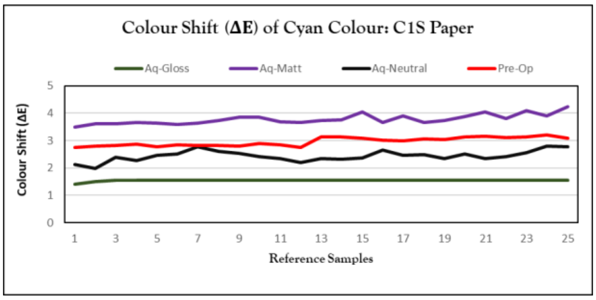

Fig. 4. Colour Shift (ΔE Colour) of Cyan colour on C1S Paper Across Aqueous Coatings (Gloss, Matt, Neutral) and Pre-Coating

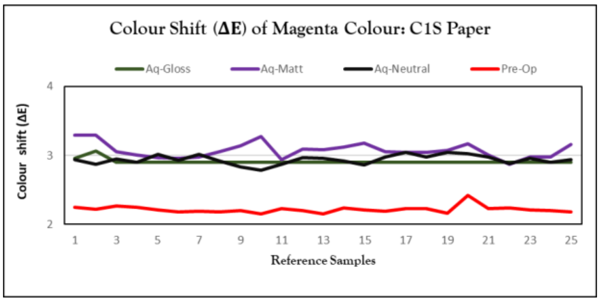

Fig. 5. Colour Shift (ΔE Colour) of Magenta colour on C1S Paper Across Aqueous Coatings (Gloss, Matt, Neutral) and Pre-Coating

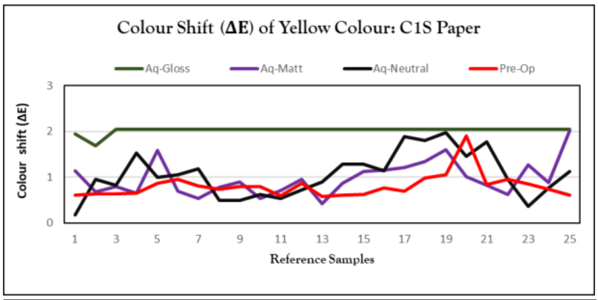

Fig. 6. Colour Shift (ΔE Colour) of Yellow colour on C1S Paper Across Aqueous Coatings (Gloss, Matt, Neutral) and Pre-Coating

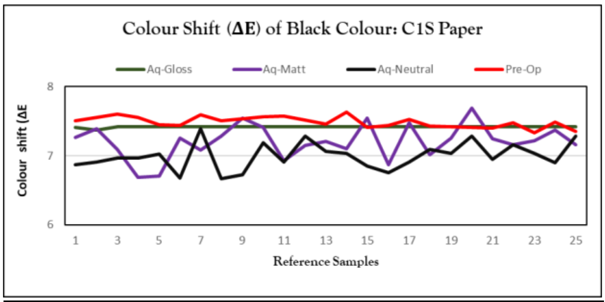

Fig. 7. Colour Shift (ΔE Colour) of Yellow colour on C1S Paper Across Aqueous Coatings (Gloss, Matt, Neutral) and Pre-Coating

This study examined the colour shift (ΔE) across Cyan, Magenta, Yellow, and Black on SBS C1S paper with three types of aqueous coatings—Gloss, Matt, and Neutral—and compared them to uncoated samples.

- **Cyan** [Fig. 4]: The uncoated ΔE for Cyan was 2.96. After applying Aqueous Gloss, the ΔE ranged from 1.40 to 1.56, showing minimal colour shift. Aqueous Matt coating caused a wider range (3.50 to 4.23), while Aqueous Neutral displayed moderate variation (1.97 to 2.80).
- **Magenta** [Fig. 5]: For Magenta, uncoated samples had a ΔE of 2.22. The ΔE with Aqueous Gloss coating ranged narrowly between 2.90 and 3.06,

indicating a minor shift. Aqueous Matt showed slightly higher variability (2.87 to 3.29), while Aqueous Neutral produced a ΔE between 2.78 and 3.04.

- **Yellow [**Fig. 6**]**: Yellow's uncoated ΔE was 0.81. After Aqueous Gloss coating, ΔE shifted between 1.69 and 2.05, showing a mild increase. Aqueous Matt exhibited a larger range (0.42 to 2.02), while Aqueous Neutral varied from 0.17 to 1.98, indicating moderate colour shifts.
- **Black [**Fig. 7**]**: The ΔE for Black on uncoated paper was 7.49. With Aqueous Gloss, ΔE ranged minimally from 7.37 to 7.42, showing stable colour retention. Aqueous Matt displayed a broader shift (6.69 to 7.69), and Aqueous Neutral showed moderate variability (6.67 to 7.39).

2. **Colour Shift Due to Aqueous Coatings (Gloss, Matt, Neutral) on Gloss Art Paper:** The colour shift (ΔE Value) of process colours—Cyan, Magenta, Yellow, and Black—during offset printing on Gloss Art Paper with Gloss, Matt, and Neutral aqueous coatings is shown in Fig. 8, 9, 10 AND 11respectively.

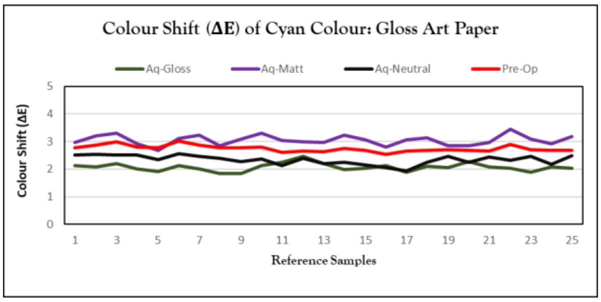

Fig. 8. Colour Shift (ΔE Colour) of Cyan colour on Gloss Art Paper Across Aqueous Coatings (Gloss, Matt, Neutral) and Pre-Coating

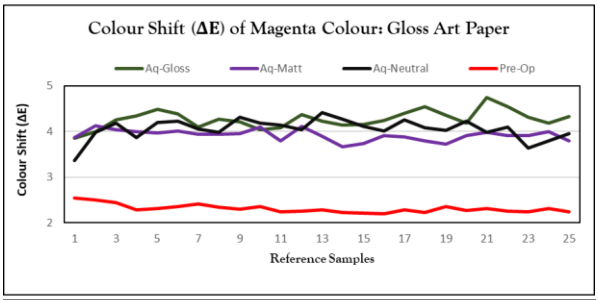

Fig. 9. Colour Shift (ΔE Colour) of Magenta colour on Gloss Art Paper Across Aqueous Coatings (Gloss, Matt, Neutral) and Pre-Coating

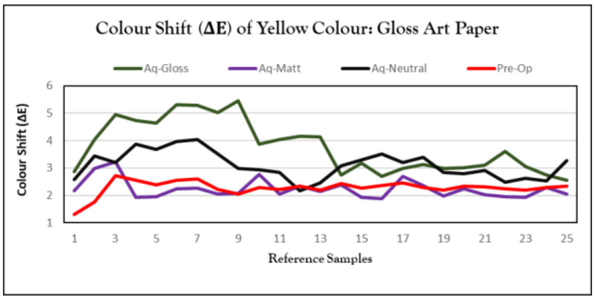

Fig. 10. Colour Shift (ΔE Colour) of Yellow colour on Gloss Art Paper Across Aqueous Coatings (Gloss, Matt, Neutral) and Pre-Coating

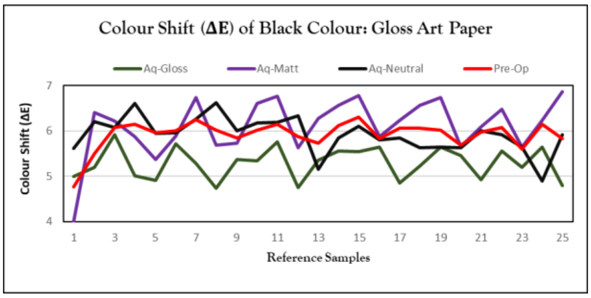

Fig. 11. Colour Shift (ΔE Colour) of Black colour on Gloss Art Paper Across Aqueous Coatings (Gloss, Matt, Neutral) and Pre-Coating

This analysis examined the colour shift (ΔE) for Cyan, Magenta, Yellow, and Black on Gloss Art Paper with three types of aqueous coatings—Gloss, Matt, and Neutral—and compared them to uncoated samples.

- **Cyan** [Fig. 8]: The uncoated ΔE for Cyan was stable at 2.96. With Aqueous Gloss coating, ΔE ranged from 1.92 to 2.21, showing minimal shift. Aqueous Matt coating led to a broader range (2.35 to 4.10), while Aqueous Neutral caused a moderate shift (2.07 to 3.50).
- **Magenta [**Fig. 9**]**: For Magenta, uncoated ΔE was 3.22. After Aqueous Gloss coating, ΔE ranged from 3.85 to 4.48, indicating minor variation. Aqueous Matt coating produced a wider range (4.00 to 5.50), while Aqueous Neutral resulted in moderate shifts (3.75 to 5.30).
- **Yellow [**Fig. 10**]**: Uncoated Yellow's ΔE was 1.80. Aqueous Gloss coating caused ΔE to shift from 2.86 to 4.95, showing moderate impact. Aqueous Matt produced a larger range (3.40 to 5.70), while Aqueous Neutral led to shifts from 2.05 to 4.80, indicating moderate variability.
- **Black [**Fig. 11**]**: The uncoated ΔE for Black was 5.50. With Aqueous Gloss, ΔE ranged minimally from 4.99 to 5.91, suggesting stable retention.

Aqueous Matt caused broader shifts (5.20 to 6.40), while Aqueous Neutral displayed moderate shifts (4.70 to 6.20).

3. **Colour Shift Due to Aqueous Coatings (Gloss, Matt, Neutral) on Matt Art Paper:** The colour shift (ΔE Value) of process colours—Cyan, Magenta, Yellow, and Black—during offset printing on Matt Art Paper with Gloss, Matt, and Neutral aqueous coatings is shown in Fig. 12, 13, 14 and 15 respectively.

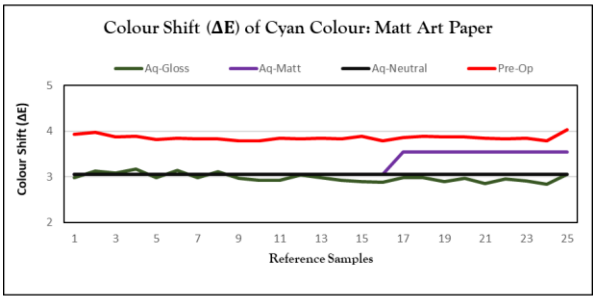

Fig. 12. Colour Shift (ΔE Colour) of Cyan colour on Matt Art Paper Across Aqueous Coatings (Gloss, Matt, Neutral) and Pre-Coating

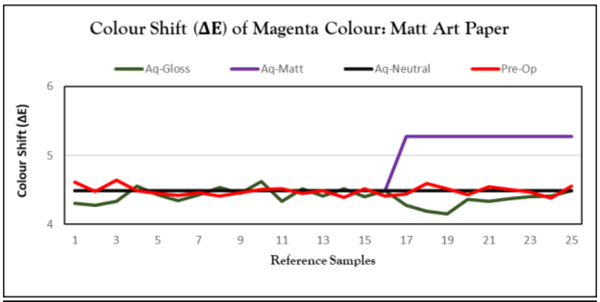

Fig. 13. Colour Shift (ΔE Colour) of Magenta colour on Matt Art Paper Across Aqueous Coatings (Gloss, Matt, Neutral) and Pre-Coating

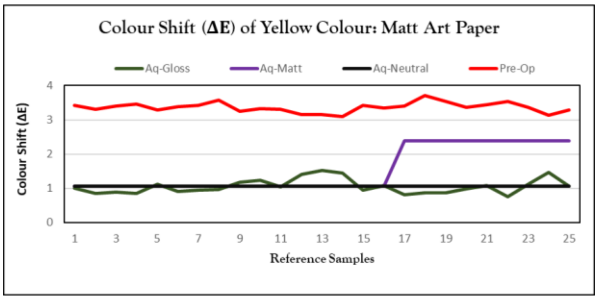

Fig. 14. Colour Shift (ΔE Colour) of Yellow colour on Matt Art Paper Across Aqueous Coatings (Gloss, Matt, Neutral) and Pre-Coating

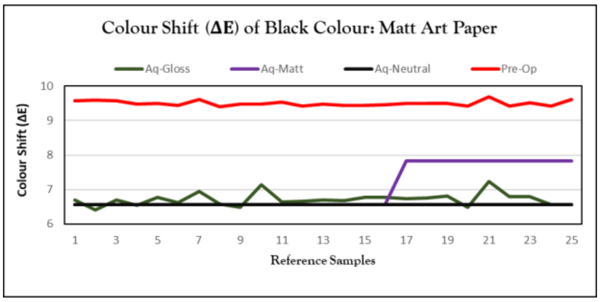

Fig. 15. Colour Shift (ΔE Colour) of Black colour on Matt Art Paper Across Aqueous Coatings (Gloss, Matt, Neutral) and Pre-Coating

This analysis reviewed the colour shift (ΔE) for Cyan, Magenta, Yellow, and Black on Matt Art Paper with three aqueous coatings—Gloss, Matt, and Neutral—and compared them to uncoated samples.

- **Cyan [**Fig. 12**]**: The uncoated ΔE for Cyan was stable. With Aqueous Gloss coating, ΔE ranged from 2.99 to 3.17, indicating minimal colour shift. Aqueous Matt coating resulted in a broader range (3.48 to 4.52), while Aqueous Neutral caused a moderate shift (2.70 to 3.95).
- **Magenta [**Fig. 13**]**: For Magenta, uncoated ΔE was consistent. Aqueous Gloss coating caused ΔE to range from 4.28 to 4.55, suggesting minor variation. Aqueous Matt coating produced a wider range (4.72 to 5.85), while Aqueous Neutral showed moderate shifts (4.15 to 5.63).
- **Yellow [**Fig. 14**]**: Uncoated Yellow's ΔE was low. Aqueous Gloss coating shifted ΔE from 0.86 to 1.12, showing a mild effect. Aqueous Matt caused a more noticeable range (1.18 to 2.53), while Aqueous Neutral resulted in a moderate shift (0.75 to 1.89).
- **Black [**Fig. 15**]**: The uncoated ΔE for Black was stable. Aqueous Gloss coating caused ΔE to range from 6.41 to 6.77, indicating minimal variation. Aqueous Matt showed broader shifts (6.52 to 7.31), while Aqueous Neutral caused moderate variability (6.05 to 7.10).

5. Results and Discussion

The detailed comparative analysis requires evaluating the ΔE values, depicting Colour shift, for each paper type (C1S Paper in Table 3, Gloss Art Paper in Table 4, and Matt Art Paper in Table 5) for each colour and each coating type. This approach will highlight how each coating type affects the colour shift when applied to different paper types and colours.

We'll go through each table individually, comparing the mean, standard deviation, minimum, and maximum ΔE values for each coating (Aqueous Gloss, Aqueous Matt, and Aqueous Neutral) against the baseline no-coating ΔE values.

Table 3: C1S Paper Analysis by Colour and Coating Type

C1S Paper					
Colour	Coating	Mean	Std. Dev	Min.	Max.
Cyan	Aqueous Gloss	1.55	0.03	1.40	1.56
	Aqueous Matt	3.78	0.18	3.50	4.23
	Aqueous Neutral	2.44	0.20	1.97	2.80
	No Coating	2.96	0.15	2.75	3.20
Colour	Coating	Mean	Std. Dev	Min.	Max.
Magenta	Aqueous Gloss	2.91	0.03	2.90	3.06
	Aqueous Matt	3.07	0.11	2.87	3.29
	Aqueous Neutral	2.94	0.07	2.78	3.04
	No Coating	2.22	0.05	2.15	2.42
Colour	Coating	Mean	Std. Dev	Min.	Max.
Yellow	Aqueous Gloss	2.03	0.07	1.69	2.05
	Aqueous Matt	0.97	0.38	0.42	2.02
	Aqueous Neutral	1.05	0.49	0.17	1.98
	No Coating	0.81	0.27	0.58	1.90
Colour	Coating	Mean	Std. Dev	Min.	Max.
Black	Aqueous Gloss	7.42	0.01	7.37	7.42
	Aqueous Matt	7.21	0.25	6.69	7.69
	Aqueous Neutral	7.00	0.19	6.67	7.39
	No Coating	7.49	0.08	7.34	7.64

Table 3: Colour Shift (ΔE Value) due to various Coating Techniques on C1S Paper

Cyan

- No Coating: Mean ΔE of 2.9613, Std Dev 0.1518.
- Aqueous Gloss: Significantly lower mean ΔE of 1.5516, with a low Std Dev of 0.0331, indicating a stable and reduced colour shift.
- Aqueous Matt: Higher mean ΔE of 3.776, showing an increased colour shift with higher variability (Std Dev 0.1819), indicating less consistency.
- Aqueous Neutral: Lower than no coating at 2.4364, with moderate variability (Std Dev 0.1967). Offers some reduction in colour shift but with moderate consistency.

Result: Aqueous Gloss shows the least colour shift and the highest consistency for cyan on C1S paper, while Aqueous Matt increases colour shift the most.

Magenta

- No Coating: Mean ΔE of 2.2159, Std Dev 0.0511.
- Aqueous Gloss: Higher mean ΔE of 2.9088 but with low Std Dev (0.0337), showing a stable yet stronger colour shift.
- Aqueous Matt: Highest mean ΔE of 3.0708, with more variability (Std Dev 0.1101), indicating less stability.
- Aqueous Neutral: Moderate increase to 2.9376 with intermediate consistency (Std Dev 0.0659).

Result: Aqueous Gloss provides a higher yet stable color shift, while Aqueous Matt introduces the most inconsistency for magenta.

Yellow

- No Coating: Mean ΔE of 0.8064, Std Dev 0.2665.

- Aqueous Gloss: Significant increase to 2.0312, with improved consistency (Std Dev 0.0744).
- Aqueous Matt: Small increase in ΔE to 0.9732 but with greater inconsistency (Std Dev 0.3817).
- Aqueous Neutral: Increased ΔE to 1.0524 with high variability (Std Dev 0.4909).

Result: Aqueous Gloss introduces the most consistent but higher colour shift. Aqueous Matt shows a milder colour shift but with more variability.

Black

- No Coating: Mean ΔE of 7.4872, Std Dev 0.0794.
- Aqueous Gloss: Slightly reduced ΔE to 7.4176 with excellent consistency (Std Dev 0.0101).
- Aqueous Matt: Lower ΔE at 7.2056 but higher variability (Std Dev 0.2461).
- Aqueous Neutral: Noticeably lower ΔE at 6.996, with moderate variability (Std Dev 0.1930).

Result: Aqueous Gloss and Aqueous Neutral both reduce colour shift for black, with Aqueous Gloss being more consistent.

Table 4: Gloss Art Paper Analysis by Colour and Coating Type

Gloss art paper					
Colour	Coating	Mean	Std. Dev	Min.	Max.
Cyan	Aqueous Gloss	2.07	0.15	1.83	2.47
	Aqueous Matt	3.05	0.18	2.69	3.44
	Aqueous Neutral	2.34	0.17	1.94	2.55
	No Coating	2.75	0.12	2.54	3.03
Colour	Coating	Mean	Std. Dev	Min.	Max.
Magenta	Aqueous Gloss	4.27	0.19	3.85	4.74
	Aqueous Matt	3.92	0.12	3.66	4.12
	Aqueous Neutral	4.05	0.22	3.36	4.42
	No Coating	2.31	0.09	2.19	2.54
Colour	Coating	Mean	Std. Dev	Min.	Max.
Yellow	Aqueous Gloss	3.77	0.95	2.56	5.46
	Aqueous Matt	2.24	0.35	1.87	3.22
	Aqueous Neutral	3.10	0.50	2.17	4.04
	No Coating	2.28	0.28	1.30	2.72
Colour	Coating	Mean	Std. Dev	Min.	Max.
Black	Aqueous Gloss	5.29	0.35	4.73	5.91
	Aqueous Matt	6.12	0.62	4.01	6.86
	Aqueous Neutral	5.92	0.39	4.89	6.62
	No Coating	5.92	0.31	4.76	6.31

Table 4: Colour Shift (ΔE Value) due to various Coating Techniques on Gloss Art Paper

Cyan

- No Coating: Mean ΔE of 2.7483, Std Dev 0.1178.
- Aqueous Gloss: Lower ΔE of 2.0708 with moderate consistency (Std Dev 0.1468).
- Aqueous Matt: Higher mean ΔE of 3.0488 with a relatively high Std Dev (0.1783).
- Aqueous Neutral: Moderate mean ΔE of 2.3392 with a similar Std Dev (0.1660).

Result: Aqueous Gloss provides the least colour shift for cyan on gloss art paper, while Aqueous Matt introduces the highest colour shift.

Magenta

- No Coating: Mean ΔE of 2.3109, Std Dev 0.0878.

- Aqueous Gloss: Highest mean ΔE of 4.268 with moderate consistency (Std Dev 0.1927).
- Aqueous Matt: Slightly lower ΔE at 3.9172 with improved consistency (Std Dev 0.1194).
- Aqueous Neutral: Moderate ΔE of 4.0548 with the highest variability (Std Dev 0.2246).

Result: Aqueous Gloss results in a strong colour shift for magenta but is consistent. Aqueous Matt shows reduced ΔE with high consistency, making it a more stable choice.

Yellow

- No Coating: Mean ΔE of 2.2772, Std Dev 0.2780.
- Aqueous Gloss: Highest ΔE at 3.7716 with high variability (Std Dev 0.9507).
- Aqueous Matt: Moderate ΔE of 2.2368 with more consistency (Std Dev 0.3483).
- Aqueous Neutral: ΔE of 3.104 with moderate variability (Std Dev 0.5016).

Result: Aqueous Matt is the most consistent option for yellow on gloss art paper, while Aqueous Gloss introduces a stronger and more variable colour shift.

Black

- No Coating: Mean ΔE of 5.9213, Std Dev 0.3115.
- Aqueous Gloss: Lower ΔE of 5.294 with moderate consistency (Std Dev 0.3488).
- Aqueous Matt: Higher ΔE of 6.1176 with highest variability (Std Dev 0.6210).
- Aqueous Neutral: Similar ΔE to no coating at 5.92 but with moderate consistency (Std Dev 0.3891).

Result: Aqueous Gloss reduces colour shift and provides consistency for black on gloss art paper, while Aqueous Matt increases the shift and variability.

Table 5: Matt Art Paper Analysis by Colour and Coating Type

Matt art paper					
Colour	Coating	Mean	Std. Dev	Min.	Max.
Cyan	Aqueous Gloss	2.98	0.09	2.84	3.17
	Aqueous Matt	3.23	0.24	3.06	3.54
	Aqueous Neutral	3.06	0.00	3.06	3.06
	No Coating	3.86	0.06	3.78	4.03
Colour	Coating	Mean	Std. Dev	Min.	Max.
Magenta	Aqueous Gloss	4.40	0.11	4.15	4.62
	Aqueous Matt	4.77	0.38	4.49	5.27
	Aqueous Neutral	4.49	0.00	4.49	4.49
	No Coating	4.48	0.07	4.38	4.64
Colour	Coating	Mean	Std. Dev	Min.	Max.
Yellow	Aqueous Gloss	1.06	0.21	0.76	1.52
	Aqueous Matt	1.54	0.65	1.06	2.39
	Aqueous Neutral	1.06	0.00	1.06	1.06
	No Coating	3.36	0.14	3.09	3.72
Colour	Coating	Mean	Std. Dev	Min.	Max.
Black	Aqueous Gloss	6.71	0.19	6.41	7.23
	Aqueous Matt	7.02	0.62	6.57	7.83
	Aqueous Neutral	6.57	0.00	6.57	6.57
	No Coating	9.50	0.07	9.41	9.68

Table 1: Colour Shift (ΔE Value) due to various Coating Techniques on Matt Art Paper

Cyan

- No Coating: Mean ΔE of 3.8583, Std Dev 0.0568.
- Aqueous Gloss: Lower ΔE of 2.9844 with moderate consistency (Std Dev 0.0892).

- Aqueous Matt: Higher ΔE of 3.2328 with greater inconsistency (Std Dev 0.2352).
- Aqueous Neutral: Moderate ΔE at 3.06 with high consistency (nearly zero Std Dev).

Result: Aqueous Neutral provides stable performance, while Aqueous Gloss reduces the colour shift with a slightly higher standard deviation.

Magenta

- No Coating: Mean ΔE of 4.4845, Std Dev 0.0664.
- Aqueous Gloss: Higher ΔE at 4.3964 with improved consistency (Std Dev 0.1124).
- Aqueous Matt: Highest ΔE at 4.7708 with high variability (Std Dev 0.3821).
- Aqueous Neutral: Mean ΔE of 4.49 with virtually no variability.

Result: Aqueous Neutral provides the most stable colour shift for magenta, while Aqueous Gloss also maintains consistency with a reduced colour shift.

Yellow

- No Coating: Mean ΔE of 3.3643, Std Dev 0.1448.
- Aqueous Gloss: Lower ΔE at 1.0588, with moderate variability (Std Dev 0.2136).
- Aqueous Matt: Higher mean ΔE of 1.5388 with greater variability (Std Dev 0.6516).
- Aqueous Neutral: Consistent ΔE of 1.06 with no variability.

Result: Aqueous Neutral provides a minimal and stable colour shift for yellow, while Aqueous Gloss reduces the colour shift significantly but with moderate variability.

Black

- No Coating: Mean ΔE of 9.4995, Std Dev 0.0734.
- Aqueous Gloss: Lower mean ΔE at 6.7144 with moderate consistency (Std Dev 0.1883).
- Aqueous Matt: Higher mean ΔE of 7.0236 with more variability (Std Dev 0.6173).
- Aqueous Neutral: Stable mean ΔE of 6.57 with zero variability.

Result: Aqueous Neutral provides a low and stable colour shift for black, while Aqueous Gloss reduces the colour shift with moderate consistency.

6. Conclusion

The research provides detailed insights into the effects of various aqueous coatings (Aqueous Gloss, Aqueous Matt, and Aqueous Neutral) on colour shift (ΔE) across different paper types—C1S, Gloss Art, and Matt Art. Each coating's influence varies across the four primary process colours (Cyan, Magenta, Yellow, and Black), indicating a nuanced interaction between the type of coating and the paper substrate.

Aqueous Gloss Coating

For Aqueous Gloss, the ΔE value consistently showed reductions or controlled shifts for most colours on each paper type, though some colour shifts increased depending on the specific colour and paper:

C1S Paper: The Aqueous Gloss coating generally reduced the ΔE values for Cyan and Black on C1S paper, indicating a reduced colour shift, especially for Cyan, which displayed a significant improvement in colour stability. Magenta and Yellow, however, showed a moderate increase in ΔE, indicating a slight colour shift but within a consistent range.

Gloss Art Paper: Aqueous Gloss on Gloss Art Paper resulted in a notable colour shift, particularly for Magenta and Yellow, which showed the highest ΔE values, indicating a more pronounced colour shift. Cyan experienced a reduction in ΔE compared to the uncoated baseline, suggesting better stability, while Black also benefited from slight colour stabilization, though the shift was less marked compared to C1S.

Matt Art Paper: Aqueous Gloss effectively reduced colour shift for Cyan, Yellow, and Black on Matt Art Paper, with Cyan showing a significant improvement. However, Magenta exhibited a slight increase in ΔE, though it remained relatively stable. Overall, Aqueous Gloss provided a favorable and consistent impact on colour stability for most colours, especially on Matt Art Paper.

Summary: Aqueous Gloss is effective in stabilizing Cyan and Black across all paper types, with mild increases in colour shift for Magenta and Yellow on certain substrates, particularly Gloss Art Paper. It provides reliable colour retention with minimal shifts for most colours, especially Cyan.

Aqueous Matt Coating

Aqueous Matt Coating generally increased the ΔE values across all colours and paper types, indicating a noticeable colour shift post-coating. This shift varied in magnitude depending on the paper and colour, but overall, Aqueous Matt showed more variability than Aqueous Gloss and Neutral.

C1S Paper: The ΔE values increased considerably for Cyan, Magenta, and Yellow on C1S Paper after Aqueous Matt coating, with Yellow showing the least stability. Black, however, exhibited a slight reduction in ΔE, though it remained variable across samples.

Gloss Art Paper: Aqueous Matt on Gloss Art Paper led to a prominent colour shift across all colours, particularly Black and Cyan, which saw the largest increases in ΔE. Yellow exhibited slightly more stability, though the ΔE value still indicated a significant shift compared to the uncoated baseline.

Matt Art Paper: On Matt Art Paper, Aqueous Matt displayed increased ΔE values for all colours, with the greatest shifts seen in Magenta and Yellow. Cyan and Black also saw increases, though Cyan remained relatively consistent compared to other colours on Matt Art Paper.

Summary: Aqueous Matt consistently induces a higher colour shift across all colours and paper types, especially impacting Magenta and Yellow. While it provides a slight improvement in colour stability for Black on C1S Paper, it generally causes greater shifts, making it less effective for colour retention.

Aqueous Neutral Coating

Aqueous Neutral provided moderate improvements in ΔE values across several colours and paper types, often balancing between the effects seen with Aqueous Gloss and Aqueous Matt. However, its influence varied widely, with some colours showing marked improvement while others remained relatively stable.

C1S Paper: For Cyan and Black on C1S Paper, Aqueous Neutral reduced the ΔE value, indicating a controlled colour shift, though less effective than Aqueous Gloss. Magenta and Yellow, however, showed moderate increases in ΔE, particularly Yellow, which exhibited variable consistency.

Gloss Art Paper: Aqueous Neutral resulted in reduced colour shifts for Cyan and Yellow on Gloss Art Paper, showing effective colour stability. Black also remained stable, though Magenta showed a noticeable increase in ΔE, indicating more variability for this colour.

Matt Art Paper: On Matt Art Paper, Aqueous Neutral provided the most stable performance, especially for Yellow and Black, with near-zero variability in ΔE values, indicating highly consistent results. Cyan and Magenta also remained stable, though Cyan displayed slight fluctuations.

Summary: Aqueous Neutral coating generally maintains colour stability, particularly for Black and Yellow on Matt Art Paper, and provides moderate colour shifts for most colours across all paper types. It serves as a balanced choice, offering controlled colour shifts with minimal variability.

Overall Conclusion

The study reveals that the type of aqueous coating has a distinct impact on colour shift across different paper substrates and colours:

Aqueous Gloss is ideal for reducing colour shifts in Cyan and Black across all papers, providing high consistency and minimal shift for most colours. However, it may increase shifts in Magenta and Yellow, particularly on Gloss Art Paper.

Aqueous Matt consistently induces higher colour shifts for all colours, especially impacting Magenta and Yellow, with greater variability across paper types. It is generally less suitable for colour retention.

Aqueous Neutral offers balanced performance, maintaining colour stability for Black and Yellow on Matt Art Paper and providing moderate shifts for other colours. It is a versatile option that balances colour retention and consistency across papers.

In conclusion, the study highlights that Aqueous Gloss and Aqueous Neutral are effective choices for stabilizing colours, with Aqueous Gloss excelling in Cyan and Black retention, while Aqueous Matt increases colour shifts more consistently across substrates, making it less suitable for applications requiring minimal colour shift.

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