IJISEM
INTERNATIONAL JOURNAL OF INNOVATIONS IN SCIENCE ENGINEERING AND MANAGEMENT

International Journal of Innovations In Science Engineering And Management

OPEN ACCESS

Volume: 5

Issue: 3

Month: July

Year: 2026

ISSN: 2583-7117

Published: 14.07.2026

Citation:

Bijender, Vishnu Bhambhu, Ankit Boora, "Comparative Evaluation of Print-edge Sharpness of Office-Based and Production-Based Electrophotographic Printing Systems" International Journal of Innovations in Science Engineering and Management, vol. 5, no. 3, 2026, pp. 84-89.

DOI:

10.69968/ijisem.2026v5i384-89

Comparative Evaluation of Print-edge Sharpness of Office-Based and Production-Based Electrophotographic Printing Systems

Bijender[1], Vishnu Bhambhu[2], Ankit Boora[3]

[1]*Assistant Professor, Department of Printing Technology, GJUS&T, Hisar*
[2]*M.Tech. Scholar, Department of Printing Technology, GJUS&T, Hisar*
[3]*Assistant Professor, Department of Printing Technology, GJUS&T, Hisar*

Abstract

Print-edge sharpness is one of the most important indicators of print quality, directly influencing the visual appearance, readability and reproduction accuracy of printed images and text. This paper presents a comparative evaluation of print-edge sharpness achieved by office-based and production-based electrophotographic printing systems on various paper substrates. Four commercially available paper types, namely uncoated, light-weight coated (LWC), matte coated and gloss coated papers were selected to investigate the influence of substrate characteristics on edge reproduction. Print-edge sharpness was evaluated for three image elements: line drawing edges, midtone edges and solid edges. The sharpness values were measured using human standard observer method and the performance of both printing systems was compared.

The comparative analysis reveals that the type of electrophotographic printing system and the surface characteristics of the printing substrate play a crucial role in determining print-edge sharpness. Coated papers, particularly gloss coated paper, provide significantly better edge definition than uncoated paper due to their smoother and less porous surfaces, which facilitate accurate toner deposition and fusing. The findings suggest that production-based electrophotographic presses are more suitable for high-quality commercial printing applications requiring superior image sharpness and consistency, whereas office-based presses are appropriate for routine office and short-run printing where moderate print quality is acceptable. This study provides valuable insights for selecting appropriate printing systems and substrates to achieve optimum print-edge quality in digital electrophotographic printing.

Keywords; Electrophotographic, Office-Based Printing, Production-Based Printing, Print-Edge Sharpness, Digital Printing, Toner Transfer, Coated Paper, Print Quality.

INTRODUCTION

Electrophotographic (EP) printing, commonly known as laser printing, has become one of the most widely adopted digital printing technologies in both office and commercial printing environments because of its high productivity, consistent print quality and capability for short-run and variable-data printing. Unlike conventional offset lithography, electrophotographic printing is a non-impact digital process that transfers toner particles to a substrate through electrostatic attraction and permanently fixes them using heat and pressure. The elimination of printing plates and lengthy press setup has made electrophotographic printing particularly suitable for on-demand printing, personalized printing and quick-turnaround production (Kipphan, 2001).

Electrophotographic printing systems are generally classified into two categories: office-based electrophotographic presses and production-based electrophotographic presses. Office-based systems are primarily designed for business documents, reports, educational materials and small-volume printing applications where cost-effectiveness and operational simplicity are essential. Production-based electrophotographic presses, on the other hand, are engineered for high-speed commercial printing, offering superior print resolution, advanced colour management, greater substrate compatibility and enhanced image consistency.

These presses are widely employed in commercial print shops, publishing houses, transactional printing, packaging prototypes and high-quality marketing materials (Romano, 1999).

Among the numerous quality attributes used to evaluate printed output, print-edge sharpness is regarded as one of the most significant indicators of image quality. Print-edge sharpness describes the clarity and precision with which the boundaries of printed text, graphics and image elements are reproduced. Sharp edges contribute to improved readability, better visual perception and enhanced reproduction of fine details. Poor edge sharpness results in blurred boundaries, edge raggedness and loss of image definition, ultimately reducing the perceived quality of the printed product (ISO 13660, 2001).

Several factors influence print-edge sharpness in electrophotographic printing, including toner particle size and distribution, imaging resolution, developer characteristics, fusing conditions, substrate surface properties and the overall design of the printing system. Among these variables, paper characteristics play a particularly important role because the smoothness, coating, porosity and surface energy of the substrate directly affect toner transfer, adhesion and spreading. Coated papers generally exhibit better edge definition than uncoated papers because their smoother surfaces minimize toner diffusion and improve toner fixation, resulting in sharper printed images (Bijender & Baral, 2023).

RESEARCH OBJECTIVES

Advances in electrophotographic technology have enabled production-based printing systems to achieve higher print quality through improved imaging engines, finer toner formulations, higher addressability and more sophisticated print control systems. Consequently, production presses are expected to produce sharper image edges than office-based printing systems. However, the extent of improvement depends not only on the printing technology but also on the interaction between the printing system and the printing substrate. A systematic comparison of office-based and production-based electrophotographic printing systems across different paper types is therefore essential for understanding their relative performance and identifying suitable substrate combinations for achieving optimum print quality.

This study aims to comparatively evaluate the print-edge sharpness of office-based and production-based electrophotographic printing systems using four commonly used paper substrates, namely uncoated, light-weight coated (LWC), matte coated and gloss coated papers. Print-edge sharpness is assessed for three image components: line drawing edges, midtone edges and solid edges. By comparing the performance of the two electrophotographic printing systems under identical substrate conditions, the study seeks to determine the influence of paper characteristics on edge reproduction and to identify the printing system that delivers superior image sharpness. The findings are expected to provide useful guidance for researchers, print service providers and the printing industry in selecting appropriate printing technologies and substrates for high-quality digital printing applications.

RESEARCH METHODOLOGY

The present study adopted an experimental and comparative research design to evaluate the print quality performance of office-based and production-based electrophotographic printing systems. The methodology was developed to provide a systematic comparison of the print outputs produced by both categories of printing systems under controlled operating conditions. The study primarily focused on assessing the influence of machine configuration, printing speed, substrate characteristics and operational conditions on various print quality parameters. Objective measurements and statistical analysis were employed to establish the comparative performance of the selected electrophotographic printing systems.

Two categories of electrophotographic printing systems, namely office-based and production-based printers, were selected for the investigation and given name Press-I and Press-II respectively. The selected printers represented commonly used digital printing technologies employed in office documentation and commercial print production. Prior to experimentation, all printing systems were inspected to ensure proper working condition and were configured according to the manufacturer's recommended operating settings. Wherever possible, identical printing parameters, including print resolution, colour settings and page layout, were maintained throughout the experimental work to eliminate unnecessary variations in the printed output.

A common digital test artwork was prepared to evaluate different print quality characteristics. The artwork consisted of solid colour patches, halftone patches, fine lines, positive and negative text, registration marks, grayscale elements and photographic images. The same digital file was printed on each electrophotographic printing system to maintain consistency throughout the study. The use of identical artwork ensured that any variation observed in print quality resulted from differences in the printing systems rather than differences in image content.

Different paper substrates commonly used in office and commercial printing applications were selected for experimentation. The selected substrates differed in grammage and surface finish to examine their influence on print quality. Before printing, the paper samples were properly conditioned to the laboratory environment to minimize variations arising from changes in moisture content. The substrates were carefully inspected to ensure uniformity in size, thickness and surface condition before they were loaded into the respective printing systems.

Print-edge sharpness was assessed by examining the reproduction of fine image details using digital microscopic imaging by standard human observers on the scale 1-10. Edge definition, transition smoothness and clarity of printed images were analysed to determine the sharpness characteristics of each printing system. Particular attention was given to the reproduction of fine image structures that are commonly encountered in commercial printing applications.

Line quality was evaluated by examining horizontal, vertical and diagonal lines of varying thickness incorporated into the test artwork. Measurements focused on line continuity, edge smoothness, line width variation and the presence of distortions or irregularities. Similarly, text quality was evaluated using printed characters of different font sizes and styles. The clarity of character edges, stroke uniformity, readability and reproduction of fine textual details were examined to compare the text rendering capabilities of the selected electrophotographic printing systems.

DATA COLLECTION AND ANALYSIS

The data for this study were collected by printing standardized test targets on four different paper substrates, namely uncoated, light-weight coated (LWC), matte coated and gloss coated papers, using an office-based electrophotographic press and a production-based electrophotographic press under controlled printing conditions. The printed samples were evaluated for print-edge sharpness in three image categories: line drawing edges, midtone edges and solid edges. Multiple print samples were produced for each paper type to ensure the reliability and consistency of the measurements.

The collected data were analysed by comparing the print-edge sharpness index obtained for each paper substrate and printing system. Descriptive statistical techniques, including mean values and graphical representations, were used to examine variations in edge sharpness among the different substrates and between the two electrophotographic printing systems. The comparative analysis enabled the identification of the paper type and printing system that produced the highest print-edge sharpness and overall print quality.

Table 1 Print-Edge Sharpness of Press-I

	Line Drawing Edges	Midtone Edges	Solid Edges
Uncoated	4.15	5.13	5.35
LWC Paper	4.73	5.95	6.23
Matte Coated	6.72	7.32	7.37
Gloss Coated	7.13	8.04	8.27

Table 1 presents the Print-edge Sharpness results for Press-I (Office-based Electrophotographic Press) show that the type of paper has a significant influence on the quality of printed edges. Among the four paper substrates tested, uncoated paper produced the lowest edge sharpness values for all image elements, recording 4.15 for line drawing edges, 5.13 for midtone edges and 5.35 for solid edges. These lower values are primarily due to the rough and porous surface of uncoated paper, which allows toner particles to spread slightly and results in less defined edges. LWC (Light Weight Coated) paper showed a moderate improvement, with edge sharpness values increasing to 4.73 for line drawings, 5.95 for midtones and 6.23 for solid areas. The coated surface of LWC paper provides a smoother printing substrate, enabling better toner transfer and improved edge definition compared to uncoated paper. A substantial enhancement in print-edge sharpness was observed on matte coated paper, which recorded values of 6.72 for line drawings, 7.32 for midtones and 7.37 for solid edges. The smooth coated surface minimizes toner spread and allows the electrophotographic process to reproduce images with greater precision and clarity. Gloss coated paper exhibited the highest print-edge sharpness across all three image categories, achieving values of 7.13 for line drawing edges, 8.04 for midtone edges and 8.27 for solid edges. Its highly smooth and non-porous surface facilitates precise toner placement, producing the sharpest and most well-defined printed edges. Overall, the results demonstrate a consistent increase in print-edge sharpness with improvements in paper surface quality. As the substrate changes from uncoated to LWC, matte coated and finally gloss coated paper, the edge sharpness values steadily increase for line drawings, midtones and solid areas. This indicates that coated papers, particularly gloss coated paper, provide superior image reproduction and are better suited for office-based electrophotographic printing applications where high print quality and crisp image detail are required.

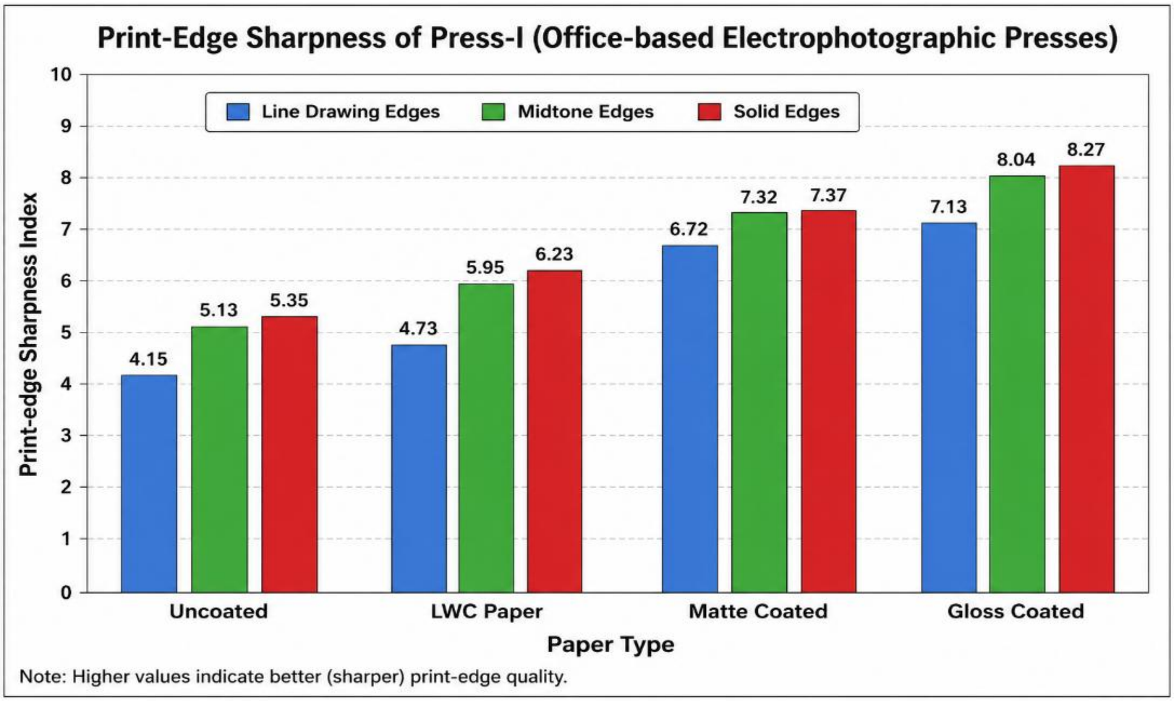

Figure 1 Print-Edge Sharpness of Press-I on Different Papers

Table 2 Print-Edge Sharpness Index of Press-II

	Line Drawing Edges	Midtone Edges	Solid Edges
Uncoated	5.05	6.25	6.33
LWC Paper	6.15	6.95	7.12
Matte Coated	7.98	8.05	8.25
Gloss Coated	8.15	8.65	8.85

The table 2 and corresponding graph present the print-edge sharpness performance of Press-II (Production-based Electrophotographic Presses) on four different paper substrates: uncoated, LWC (Light Weight Coated), matte coated and gloss coated paper. The print-edge sharpness index was measured for three image elements, namely line drawing edges, midtone edges and solid edges. The results clearly demonstrate that the quality of print edges improves progressively as the paper surface becomes smoother and more highly coated.

Among all the paper types, uncoated paper exhibited the lowest print-edge sharpness values, recording 5.05 for line drawing edges, 6.25 for midtone edges and 6.33 for solid edges. The relatively rough and porous surface of uncoated paper causes slight toner spreading during the electrophotographic printing process, resulting in less distinct image boundaries. Although the production-based press performs better than an office-based press even on uncoated paper, the substrate still limits the maximum achievable sharpness.

LWC paper showed a noticeable improvement in print-edge sharpness, with values increasing to 6.15 for line drawing edges, 6.95 for midtone edges and 7.12 for solid edges. The light coating on the paper provides a smoother and more uniform printing surface, allowing toner particles to be transferred and fused more accurately. Consequently, finer details, smoother tonal transitions and cleaner solid edges are produced compared with uncoated paper.

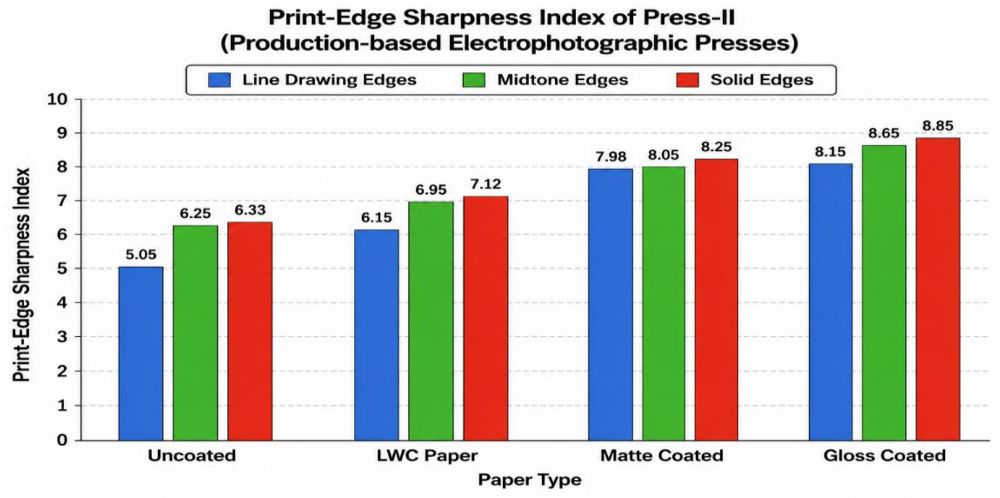

Figure 2 Print-Edge Sharpness of Press-II on Different Papers

Matte coated paper further enhanced print quality, producing edge sharpness values of 7.98 for line drawing edges, 8.05 for midtone edges and 8.25 for solid edges. The smooth coated surface minimizes toner spread and ensures precise toner adhesion, resulting in excellent reproduction of fine lines, improved midtone definition and sharp solid image boundaries. The graph clearly illustrates this substantial increase in sharpness compared with both uncoated and LWC papers.

Table 2 presents the print-edge sharpness of the production-based electrophotographic printing system (Press-II) across different paper substrates, demonstrating the significant influence of substrate surface characteristics on image definition. The results indicate a progressive improvement in edge sharpness from rough uncoated paper to gloss coated paper for line drawings, midtones and solid image areas. On rough uncoated paper, the production-based press recorded the lowest sharpness values, with 4.15 for line drawing edges, 5.13 for midtone edges and 5.35 for solid edges.

The porous and rough surface of the uncoated substrate promotes toner penetration and edge diffusion, thereby reducing image clarity. When printed on LWC paper, the sharpness values increased to 4.73, 5.95 and 6.23, respectively, indicating improved toner holdout and better edge definition due to the smoother coated surface. Matte coated paper further enhanced print-edge sharpness, producing values of 6.72, 7.32 and 7.37 for line, midtone and solid edges, respectively, reflecting improved toner fusion and more precise edge reproduction. The highest sharpness values were obtained on gloss coated paper, where line drawing edges, midtone edges and solid edges reached 7.13, 8.04 and 8.27, respectively. The smooth and highly coated surface of gloss paper minimizes toner spread and maximizes edge definition, resulting in the sharpest and most visually distinct printed images.

When compared with the production-based electrophotographic printing system (Press-II), both presses exhibited the same overall trend of increasing sharpness with improving paper surface quality. However, Press-II produced slightly higher edge sharpness values across all paper categories, particularly on matte and gloss coated papers. This suggests that while the production-based press demonstrated superior performance in Solid Ink Density and Print Contrast, the production-based press provided marginally better edge definition under the experimental conditions. The difference is likely attributable to variations in toner particle characteristics, image processing algorithms, edge enhancement techniques and fusing conditions rather than substrate effects alone. Nevertheless, both printing systems achieved their highest image sharpness on gloss coated paper, confirming that substrate smoothness plays a dominant role in determining edge quality in electrophotographic printing.

RESULTS AND DISCUSSION

Print-edge sharpness determines the visual clarity of printed graphics, text and fine details. It is particularly important in commercial printing where small text, line art and photographic details must be reproduced accurately. The results demonstrated that substrate smoothness had a pronounced influence on edge sharpness. Both printing systems exhibited progressive improvements from rough uncoated paper to gloss coated paper. Press-II (Production-based EP Press) produced slightly higher sharpness values than Press-I (Office-based EP Press) across all paper categories. This observation suggests that the production-based electrophotographic system employed finer toner particle characteristics or a more conservative toner laydown, resulting in reduced edge spread and improved edge definition.

The superior sharpness obtained on gloss coated paper can be explained by its extremely smooth surface, which minimizes toner diffusion and preserves edge geometry during the fusing process. Matte coated paper also produced excellent edge quality while avoiding the glare associated with gloss finishes. The relatively poor sharpness observed on rough uncoated paper results from increased toner penetration, fibre irregularities and surface roughness, all of which reduce edge definition and image clarity. Overall, both printing systems demonstrated significant improvements in sharpness with coated substrates, although Press-II showed a slight advantage in preserving fine image details.

CONCLUSION

From all above result and discussions, it is concluded that the Print-edge Sharpness measurements indicated continuous improvement from rough uncoated paper to gloss coated paper for both printing systems. Gloss coated paper produced the sharpest line edges, midtone transitions and solid image boundaries due to its smooth surface and superior toner holdout. The production-based system showed a slight advantage in edge sharpness, suggesting finer control over toner spread and edge definition. Among the four substrates evaluated, gloss coated paper consistently produced the best overall print quality, followed closely by matte coated paper. These coated substrates provided higher solid ink densities, lower tonal value increase, greater print contrast and superior image sharpness compared with LWC and rough uncoated papers. The results clearly demonstrate that substrate surface characteristics play a critical role in determining the final print quality of electrophotographic printing systems.

The findings of this research contribute valuable information for printing industries, researchers and equipment manufacturers by providing a scientific basis for selecting appropriate electrophotographic printing systems and paper substrates according to specific print quality requirements. Furthermore, the study establishes a useful framework for future investigations involving additional print quality attributes, advanced colour management techniques and emerging electrophotographic printing technologies.

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