

Article

Elimination of the Solid Graininess Issue with Different Micro-Pattern Structures at Flexo Printing

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Featured Application: Developed micro-patterns in order to print smooth solid ink laydowns with flexo printing.

Abstract: Flexo printing is a relief printing system, and ink transfers on the solid areas are not transferring well during the printing. That is why graininess is increasing and pinholes are occurring on the solid areas. This is a well-known issue in the flexo printing system. Micro-patterns usually eliminate these pinholes. Using correct micro-patterns allows homogeneous ink laydown and increases solid ink density. Micro-pattern holes behave like gravure cylinders on plate surfaces, and this makes for better ink transfer to the substrate. In this study, a more successful micro-pattern structure than the ones currently used was found by examining the solid ink density (SID) values and ink laydown obtained from the structure by producing eight different micro-pattern structures of 1000 LPI and 1500 LPI (line per inch) pattern screen frequencies with the same polymer structure and type. Densitometric values of solid prints made with the developed micro-patterns were measured. By eliminating the pinholes formed in solid prints and at the screen dot shapes, the ink is distributed more homogeneously without graininess. It has been determined that this results in a more stable measurement of ink density and eliminates the measurement of excess ink and low density.

Keywords: flexo printing; flexo plates; micro-pattern; ink spreading; image analysis

Citation: Kesan, N.; Sahinbaskan, T. Elimination of the Solid Graininess Issue with Different Micro-Pattern Structures at Flexo Printing. *Appl. Sci.* **2024**, *14*, 8130. <https://doi.org/10.3390/app14188130>

Academic Editor: Kambiz Vafai

Received: 8 July 2024

Revised: 16 August 2024

Accepted: 3 September 2024

Published: 10 September 2024



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1. Introduction

A relief printing plate is used as a printing form in flexographic printing. The printing plate is mounted onto the printing cylinder using an adequate substructure with defined height and compressibility [1]. Flexo printing systems are widely used in applications such as plastics, paper, cardboard packaging, and packaging labels [2]. Due to the ability to print a wide variety of functional inks on different substrates, this highly efficient technology has also been successfully applied in various printed electronics applications, such as microscale conductive networks [3]. Figure 1 shows us the flexo printing system: the fountain roller transferring inks to the anilox roller; the anilox roller transferring inks to the printing plate; and the printing plate transferring inks to the substrate.

Computer-to-plate (CTP) technology processes the image areas on the opaque layer on the plate surface and makes them ready for exposure. As micro-patterns begin to be created, a more evenly distributed ink layer begins to be created on the surface. The purpose of the micro-patterns created on the plate is to create various pits in the solid areas on the plate so that printing can be carried out with lower volume aniloxes with less ink consumption. It will provide a high level of performance by using smaller micro-patterns along with CTP and developing technology [4,5].

There are many process parameters that can affect print quality in flexography [6], such as the surface structure of the plate surface [7], anilox cell volume and frequency [8], printing speed, applied pressure, and ink [9].

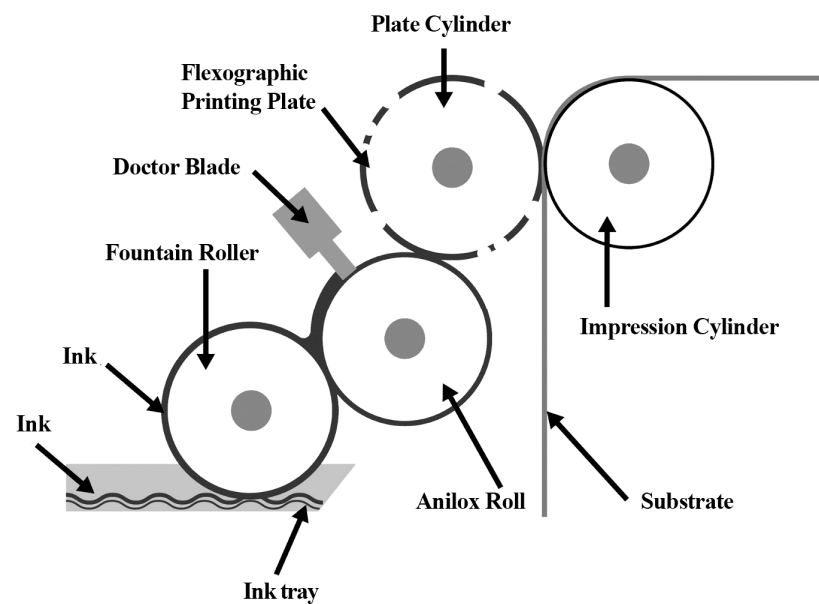


Figure 1. Flexo printing system.

The correct amount of ink required to transfer to the printing plate is controlled by adjusting the engraved cell parameters. The capacity of ink on an anilox roller is usually stated in cubic centimeters of ink per square meter; this is an estimate of the maximum theoretical ink transfer to the substrate [10].

Various techniques and methods have been developed for the evaluation and characterization of flexographic printing plates according to their performance. For the three types of plates (i.e., rubber, liquid photopolymer, and solid sheet photopolymer plates), the basic principles and methods used in the evaluations are similar. Important properties include volume, surface, and application properties (e.g., resistance to solvents and inks) [1].

Figure 2 shows us flexo printing plates in lateral view. Relief depth affects the printed line width and dot size as it plays a role in the deformation of the plate. For instance, deep relief depth makes it easier to be affected by external impacts. Lower relief depth makes a stronger plate. Relief depth should be balanced by plate thickness in order to correct relief depth and should follow the manufacturer's recommendations. In recent years, great advances in the development of photopolymer printing plates have increased the quality of flexography, making it a strong competitor for printing processes. However, there are many process parameters that can affect print quality in flexography printing. There is little research on the parametric study of flexography, and this provides the opportunity for further study [6].

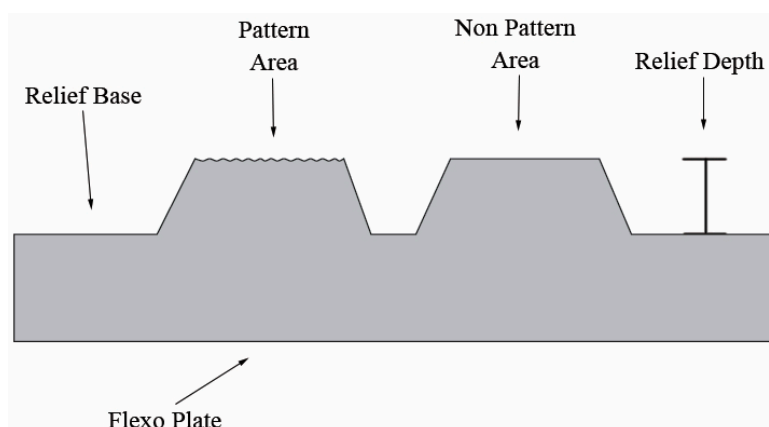


Figure 2. Fotopolymer flexo printing plate.

One of the most important elements affecting the print quality in flexo printing systems is the choice of plates [11]. The plate is prepared before the real printing starts, while the dot gain is observed via the test printing at the conditions desired to be produced [12]. The dot gain adjustments required for the preparation of the plate are made based on the results of this process, and the plates are prepared. The important thing here is that each printing variable remains fixed so that optimal plates are prepared. By managing how the printing variables affect the printing process, unnecessary waste of time is prevented, and the plates at the right properties are prepared in one sitting. Computer-to-plate imager technology is used to process plates.

Flexography is challenging with gravure printing-related ink transfer achievement. In principle, flexo printing ink transfer directly connects anilox volume; it can make low-volume cell aniloxes printing solids worse than gravure. Micropatterns significantly increase solid ink density in flexo with plastic film substrate. Micro-patterns transferring ink to the solid area better, increasing SID, the characters, lines, and the edge of the solid area can easily result in better ink laydown. Micro-pattern application on the flexographic plate has a higher SID than the non-pattern part, which has also become a block to the quality of the flexographic printing [13]. Micro-patterns also increase ink coverage for white color with transparent plastic film substrates [14]. Mechanical printing settings, press speed, and surface tension of inks also affect ink transfer [15].

The ability of a printing system to reproduce a sharp image with clear details is vital for high-quality reproduction. The geometry of the printed elements, sharpness, and noise of the edges, together with a uniform ink layer, are important indicators of quality production that need to be analyzed. They are directly linked to the reproduction of lines, texts, and dots that are part of every image. Quality parameters of thin elements can be evaluated by measuring line wicking, which makes lines and text blurry or thick [16].

The goal of this research is to print at higher solid ink density and obtain less grainy solids with generated various micro-patterns. Printing conditions were stable, and only micro-patterns were changed. The obtained result will show differences between pattern and non-pattern surface print results.

The significance of this study is to improve the ink laydown and to provide a problem-free structure for the solid areas of the objects, such as text, graphics, barcodes, etc., with narrow web flexography. For instance, if the ink laydown is not sufficient in barcode printing, it may cause problems in use as a result of packaging.

2. Materials and Methods

Higher SID and lower graininess were targeted in this research. To obtain these targets, some parameters have been changed on digital plate-making systems, and then, these different parameters were tested in stable flexographic printing. Then, the test results were measured.

The methodology of this research is as follows:

- Digital plate-making,
- Flexographic printing,
- Measurement process.

2.1. Digital Plate-Making

In this study, various micro-patterns were imaged as controlled on the Cyrel EFX flat top plate with an ESKO CDI imager and processed in DuPont Cyrel Fast thermal plate-making technology. In the printing results obtained with these micro-patterns, the solid ink density and graininess were measured. As a flexography plate, DuPont Cyrel EFX (flat top dot thermal smooth surface plate, which is producible with controlled micro-patterns) was used. The thickness of the plate was 1.14 mm. The durometer of the plate was 76 Shore A. The printing of the plates was carried out in conditions consistent with the TAPPI T402 SP-13 [17] standards and in one day at the same environment.

Plate-making process specification are as follows:

- Digital Imager (CtP Device): ESKO CDI Spark 4835 (ESKO, Ghent, Belgium);
- Resolution: 4000 dpi;
- Photopolymer: DuPont Cyrel EFX 045 Digital Plate;
- Plate thickness: 1.14 mm;
- Plate Exposure UV-A Output: 22 mW/cm²;
- Line ruling: 150 lpi;
- Screen angle: 37.5°;
- Screening type: Circular AM;
- Micro-pattern line rulings: 1000 lpi, 1500 lpi;
- Pattern angle: 45°.

2.2. Printing

In these tests performed on the Omet XFlex X4 press (Omet, Lecco, Italy), Flint Group Flexocure Force UV-cured ink cyan color was used during the tests. Cyan was chosen in this test because K is often used for the shadows. Yellow is a color in which we cannot see details. We could use cyan or magenta in the CMYK process color system. Anilox was Harper, screen ruling was 375 L/cm, and a cell volume of 3.1 cm²/m³ was used. Tesa Softprint® Steelmaster open-cell foam tapes were used as plate-mounting tapes. The thickness of the mounting tape is 550 µm. Moreover, Tesa 72,022 medium-soft and Tesa 72,026 medium-hard tapes were printed. PVC and PET substrates are used.

Ink type and viscosity, anilox roller, printing pressure, and printing speed were adjusted at the same values in all test prints. All test samples are taken for measuring after printing 100 m (after print setup).

Printing specifications are as follows:

- Flexo press: Omet XFlex X4
- Printing Speed: 80 m/min;
- Flexo ink: Flint Group Flexocure Force UV cyan;
- UV Curing: UV Lamp, 600 WPI output power (Watts Per Inch);
- Printing width: 330 mm;
- Printing length: 419 mm;
- Anilox line count: 375 L/cm (950 lpi);
- Anilox cell volume: 3.1 BCM (Billion Cubic Microns);
- Plate mounting tape: Tesa 72,022 medium soft, Tesa 72,026 medium hard, 550 µm thickness;
- Substrates: PVC (polyvinyl chloride) film and PET (polyethylene terephthalate) film. Pre-treatment applied PET surface energy 42 dynes/cm and PVC film surface energy of 46 dynes/cm.

Substrate specifications:

- PVC: White monomeric, plasticized PVC film. Basis weight 112 g/m² (ISO 536) [18], caliper 84 µm (ISO 534) [19].
- PET: Clear PET film. Basis weight 105 g/m² (ISO 536), caliper 75 µm (ISO 534).

Ink mixture: Tripropylene glycol diacrylate, poropylidynetrimethanol, ethoxylated esters with acrylic acid, 4,4'-isopropylidenediphenol, oligomeric reaction products with 1-chloro-2,3-epoxypropane, esters with acrylic acid, 2-propenoic acid, 1,1'-(1,6-hexanediyl) ester, 2-propenoic acid, reaction products with pentaerythritol examethylene diacrylate [20].

2.3. Preparation of Test Plate

Control strips are formed at 1%, 2%, 3%, 4%, 5%, 10%, 20%, and 30% (to observe the highlights); 40%, 50%, and 60% (to observe the mid-tones); and 70%, 80%, and 90% (to observe the shadows) tonal values. In addition, linear and radial gradients were formed that cross over from 100% to 0%. Printed test images are given in Figure 3.

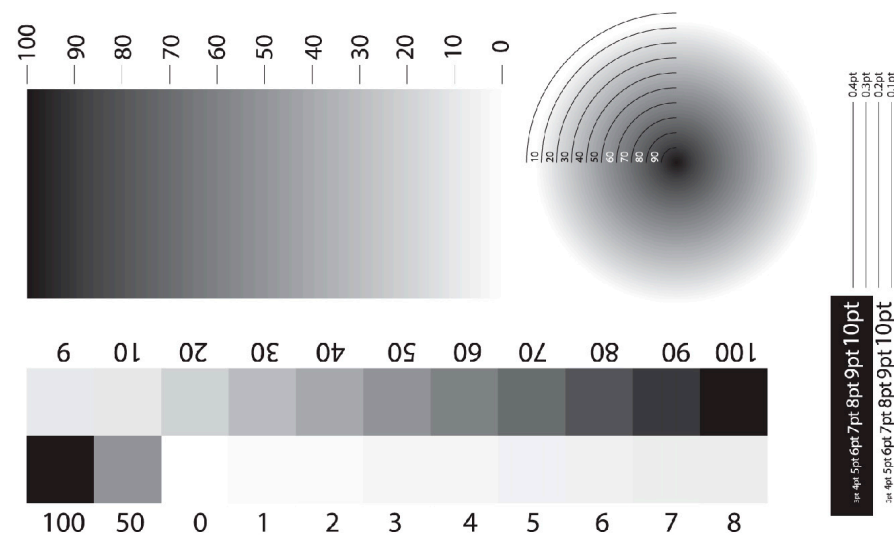


Figure 3. Printed test page.

2.4. Designing of Micro-Patterns

Eight different micro-patterns were prepared with micro-pattern-inspired rulings of 1000 lpi and 1500 lpi with angles of 45 degrees. These micro-patterns resolution was 4000 DPI (dots per inch). Pattern size was 7.62 μm , and they were repeated x- and y-coordinates. In this study, the newly developed micro-pattern types are shown in Figure 4.

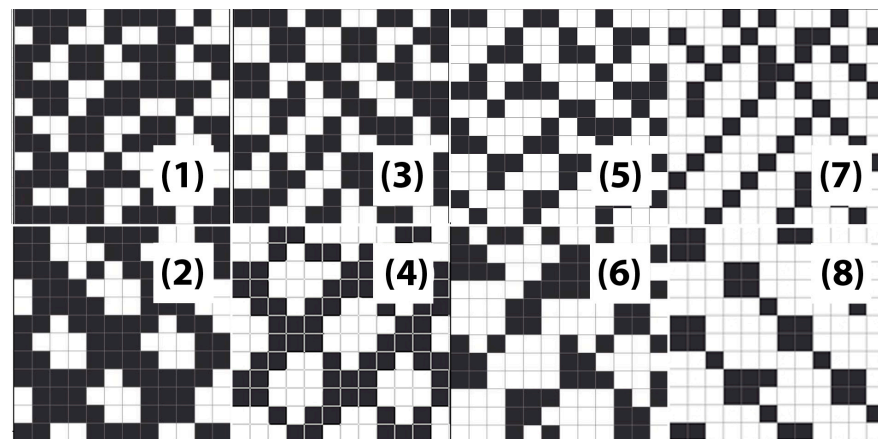


Figure 4. Designed micro-pattern types.

Patterns were designed as matrices consisting of 12 bits horizontally and vertically. Furthermore, 1 is shown as areas where the laser works, and 0 is shown as areas where the laser does not work. The structure of the matrix is described as a row from top to bottom.

Figure 2 and Tables 1 and 2 bitmap matrix forms show the shapes of micro-pattern structures that were used for the test. Micro-patterns were produced at an angle of 45°. They were randomly generated at 1500 LPI and 1000 LPI pattern screen frequencies and different tonal values. The target was to increase solid ink density and reduce graininess; micro-patterns that support high ink transfer were preferred. The smoothness in solid ink density and ink laydown is one of the important factors that determine the quality of the appearance of the print.

$$\text{Pattern size } (\mu\text{m}) = \frac{2540}{4000 \text{ ppi}} \times 12 \text{ pixel}$$

Table 1. Micro-pattern specifications.

Pattern Number	Pattern Resolutions
1	1500 lpi tonal value 60%
2	1000 lpi tonal value 60%
3	1500 lpi tonal value 50%
4	1000 lpi tonal value 50%
5	1500 lpi tonal value 40%
6	1000 lpi tonal value 40%
7	1500 lpi tonal value 30%
8	1000 lpi tonal value 30%

Table 2. Micro-pattern bitmap matrix forms.

Pattern 1	Pattern 3	Pattern 5	Pattern 7
111101111010	111011001101	110011001000	000101000100
011001001100	001100110011	000100100110	100010011001
110110111011	001100110101	001100110100	010101010100
100110011001	110011001100	010010001001	001001100010
111001111110	110101100111	110111000111	010001010001
011011100100	001100110011	001000110010	010010001000
100110011011	001001011101	100001011101	000100010100
110110111001	110011001100	110011001000	001000100010
011001001100	101010110011	001100110001	010001000101
111011101100	001100110111	001000100010	100010010100
100110011011	111001010101	100011001101	000100010100
111110111011	110011001100	010010001000	001000100010
Pattern 2	Pattern 4	Pattern 6	Pattern 8
110011110011	001100000110	101101001000	110000110000
110001100001	001011011010	110000111001	110000000000
111010110011	110000110001	111001111000	000110000000
011100011100	110001110001	000011110111	000110000000
011110011100	011011001011	000110000110	000001000010
110111110110	001110000110	000110000110	110000110000
100011100011	001110001110	101000101001	110000110000
110011110011	011001011011	110000110000	001000001000
111110111110	110001110001	110000111001	000111000110
011100011100	110001110001	000111000101	000110000110
011110011100	001011001010	000110000110	000001000001
110011110011	000110001110	000101000110	110000110000

2.5. Measurements

An X-Rite Exact NGH spectrophotometer was used for SID (solid ink density) measurements. In the measurements, solid ink density and the undesired shadows on the edges of the negative text called trail edge void were also examined. The Peret Flex 3 Pro device was used for evaluation and graininess measurements. This device is a 3D microscope that measures the quality of ink spread on the solid.

Spectrophotometer specifications are as follows:

Measurement Geometry: 45°/0° ring illumination optics, ISO 5-4:2009(E) [21].

Spectral Range: 400 nm to 700 nm with 10 nm interval

Aperture: 2 mm

Short-Term Repeatability—Density:

+/−0.01 D for CMYK measurements (non-polarized @ 2.0D)

+/−0.01 D for CMK measurements (polarized @ 2.0D)

+/−0.01 D for Y measurements (polarized @ 1.7D)

(Status E or Status T measurements)

Measurement conditions are as follows:

Measurements are made according to the ISO 13655-2009 [22] standard using the M3 settings: illumination D50, observer 2°, density status: ISO E, white base, and polarization filter. Leneta 3NT-35 paper was used as a white background in order to measure. Three samples were taken after each 1000 m and measured on different three points for solid ink density measurements. Average result were revealed and considered.

2.6. SID (Solid Ink Density)

Figure 5 shows us the working principle of the densitometer. Light from a light source was reflected onto the printed substrate. The reflected light was directed to the light sensors inside the device, and the reflected amount was calculated and displayed to the user as a value on the screen. Density was calculated using the formula in Figure 5 [23].

$$\text{Density} = \log_{10} 1/\beta$$

$$\beta = \text{Reflected light from sample} / \text{Reflected light from substrate}$$

Figure 5. SID formulation [23].

It is known that variables such as plate, ink, printing speed, anilox rollers, substrate materials, and micro-pattern application cause variability in the SID during printing. In order to achieve high SID points, high ink transfer should be managed [24].

After all patterns are printed, surface graininess was analyzed with the plot profile function. This function shows each micro-pattern graininess intensity with an x -axis and y -axis. Also, all printed pattern results and graininess were analyzed as topographic views with the 3D surface plot method.

3. Results and Discussion

The different behaviors of the different types of micropatterns created on PVC and PET printing substrates are determined by measured values. These determined values are presented below, supported by visuals.

The values obtained as a result of the measurements of eight different micro-patterns created are given in Table 3. Values marked in green are the best results; values marked in orange are the worst result.

Table 3. Micro-pattern print SID and graininess results.

Substrate	PVC				PET			
Tape	Medium-Hard Tape		Medium-Soft Tape		Medium-Hard Tape		Medium-Soft Tape	
	SID	Graininess	SID	Graininess	SID	Graininess	SID	Graininess
Non-Pattern	1.52	0.15	1.41	0.27	1.21	0.21	1.26	0.12
Pattern 1	1.55	0.13	1.61	0.14	1.29	0.19	1.4	0.08
Pattern 2	1.64	0.06	1.55	0.16	1.31	0.19	1.4	0.07
Pattern 3	1.51	0.15	1.62	0.07	1.37	0.08	1.34	0.11
Pattern 4	1.66	0.04	1.51	0.17	1.43	0.03	1.4	0.04
Pattern 5	1.32	0.29	1.25	0.45	1.2	0.27	1.14	0.35
Pattern 6	1.44	0.15	1.38	0.21	0.86	0.48	1.13	0.37
Pattern 7	0.82	0.41	0.91	0.31	0.2	0.85	0.24	0.76
Pattern 8	0.66	0.73	0.65	0.59	0.52	0.63	0.55	0.55

According to this table, Pattern 3 with medium-soft tape on PVC printing substrate has a solid ink density higher than other patterns and a non-pattern surface, and the graininess is reduced. In Pattern 4, higher solid ink density is achieved in both PVC and PET printing substrates, and less graininess is achieved compared to the SID values that do not contain micropatterns.

The printed areas magnified at $60\times$ with a microscope in solis (100%) are shown in Figures 6–14. When SID images without micro-pattern are examined, edge voids in the solid areas and rough appearance on the surface are observed. Graining is observed in the solid areas. In the PVC print substrate, shadowing occurred at points at 50% screen tone values. In PET printing material, rings are seen within the dots. These rings are caused by poor ink transfer to the solid areas.

PVC	Digital Image	Medium Hard Tape	Medium Soft Tape	PET	Digital Image	Medium Hard Tape	Medium Soft Tape
100%				100%			
50%				50%			
SID / Graininess:		1.52 / 0.15	1.47 / 0.27	SID / Graininess:		1.21 / 0.21	1.26 / 0.12
Trailing edge void:				Trailing edge void:			

Figure 6. Non-pattern print results.

PVC	Digital Image	Medium Hard Tape	Medium Soft Tape	PET	Digital Image	Medium Hard Tape	Medium Soft Tape
100%				100%			
50%				50%			
SID / Graininess:		1.55 / 0.13	1.61 / 0.14	SID / Graininess:		1.29 / 0.19	1.40 / 0.08
Trailing edge void:				Trailing edge void:			

Figure 7. Pattern 1 print results.

When the images in Figure 7 are examined, it is seen that although there is a slight increase in density in the solid areas of the micro-pattern 1 application compared to the non-pattern SIDs, there is no visual difference. It does not create a visible difference in dot areas, as it is on the solid areas.

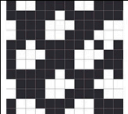
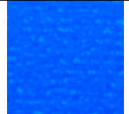
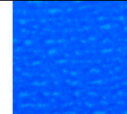
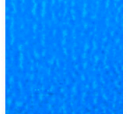
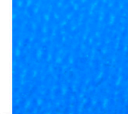
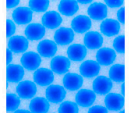
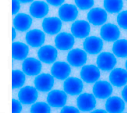
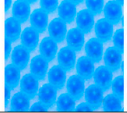
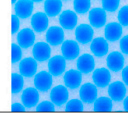
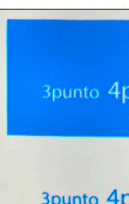
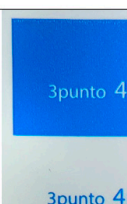
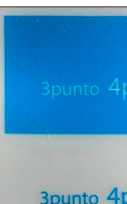
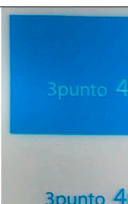
PVC	Digital Image	Medium Hard Tape	Medium Soft Tape	PET	Digital Image	Medium Hard Tape	Medium Soft Tape
100%				100%			
50%				50%			
SID / Graininess:		1.64 / 0.06	1.55 / 0.16	SID / Graininess:		1.31 / 0.19	1.40 / 0.07
Trailing edge void:				Trailing edge void:			

Figure 8. Pattern 2 print results.

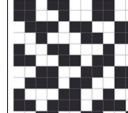
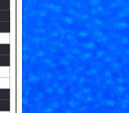
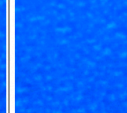
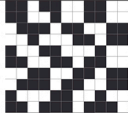
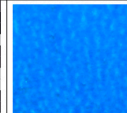
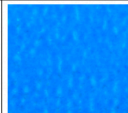
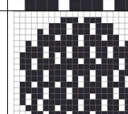
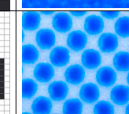
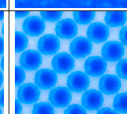
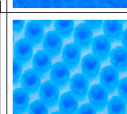
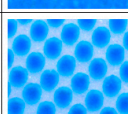
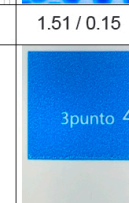
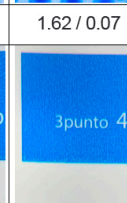
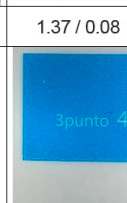
PVC	Digital Image	Medium Hard Tape	Medium Soft Tape	PET	Digital Image	Medium Hard Tape	Medium Soft Tape
100%				100%			
50%				50%			
SID / Graininess:		1.51 / 0.15	1.62 / 0.07	SID / Graininess:		1.37 / 0.08	1.34 / 0.11
Trailing edge void:				Trailing edge void:			

Figure 9. Pattern 3 print results.

When the images in Figure 8 are examined, it is seen that there is no significant difference in the density and ink laydown of the micro-pattern 2 application on the solid areas compared to the non-pattern SID and micro-pattern 1. It has been observed that the shadowing at the dots has decreased in the screening areas.

When the images in Figure 9 are examined, improvements were observed at the solid area density and ink laydown of the micro-pattern 3 application, which created on the solid areas compared to the non-pattern SID and micro-patterns 1 and 2 application. Especially in the prints made using PVC-printed Tesa 72,022 plate mounting tape, very clear results were obtained in both solid areas and screened areas.

When the images are examined according to Figure 10, it has been determined that the micro-pattern 4 application created is extremely successful in ink transfer of prints, regardless of the substrate material, both on the solid areas and in the screened areas, compared to all other developed micro-patterns on the solid areas. It has been determined that the trail edge void problem that occurs in the edge area of the printed solid areas, which is commonly encountered in flexo printing, has been completely eliminated.

PVC	Digital Image	Medium Hard Tape	Medium Soft Tape	PET	Digital Image	Medium Hard Tape	Medium Soft Tape
100%				100%			
50%				50%			
SID / Graininess:		1.66 / 0.04	1.51 / 0.17	SID / Graininess:		1.43 / 0.03	1.40 / 0.04
Trailing edge void:				Trailing edge void:			

Figure 10. Pattern 4 print results.

PVC	Digital Image	Medium Hard Tape	Medium Soft Tape	PET	Digital Image	Medium Hard Tape	Medium Soft Tape
100%				100%			
50%				50%			
SID / Graininess:		1.32 / 0.29	1.25 / 0.45	SID / Graininess:		1.20 / 0.27	1.14 / 0.35
Trailing edge void:				Trailing edge void:			

Figure 11. Pattern 5 print results.

PVC	Digital Image	Medium Hard Tape	Medium Soft Tape	PET	Digital Image	Medium Hard Tape	Medium Soft Tape
100%				100%			
50%				50%			
SID / Graininess:		1.44 / 0.15	1.38 / 0.21	SID / Graininess:		0.86 / 0.48	1.13 / 0.37
Trailing edge void:				Trailing edge void:			

Figure 12. Pattern 6 print results.

PVC	Digital Image	Medium Hard Tape	Medium Soft Tape	PET	Digital Image	Medium Hard Tape	Medium Soft Tape
100%				100%			
50%				50%			
SID / Graininess:		0.82 / 0.41	0.91 / 0.31	SID / Graininess:		0.2 / 0.85	0.24 / 0.76
Trailing edge void:				Trailing edge void:			

Figure 13. Pattern 7 print results.

PVC	Digital Image	Medium Hard Tape	Medium Soft Tape	PET	Digital Image	Medium Hard Tape	Medium Soft Tape
100%				100%			
50%				50%			
SID / Graininess:		0.66 / 0.73	0.65 / 0.59	SID / Graininess:		0.52 / 0.63	0.55 / 0.55
Trailing edge void:				Trailing edge void:			

Figure 14. Pattern 8 print results.

When the images are examined according to Figures 11–14, it is determined that the solid ink densities and screened dot areas of the micro-patterns created are gradually deteriorating and the ink transfer is extremely poor.

Newly developed micropatterns have made progress in SID compared to non-pattern systems. These SID and graininess improvements can be seen in Figures 9 and 10.

As seen in Figure 15, the most successful results with the developed micro-patterns can be achieved with an average SID of 1.65 with Pattern 4 (1000 Lpi at 50%), while the average SID without micro-patterns is 1.45.

When Figure 16 is examined, the most successful of the developed micro-patterns is Pattern 4 (1000 Lpi at 50%), and the graininess average is 0.06, while this value is 0.21 without the micro-pattern.

As seen in Figures 17 and 18, all patterns' surface graininess values were analyzed with the plot profile function. These figures show each micro-pattern graininess intensity with x -axis and y -axis; gray value 0 shows the darkest area and higher values show the lightest areas. All printed pattern results graininess is analyzed as topographic views with the 3D surface plot method. This also shows graininess intensity; the best results are shown as closer flatwise (Figures 19–27).

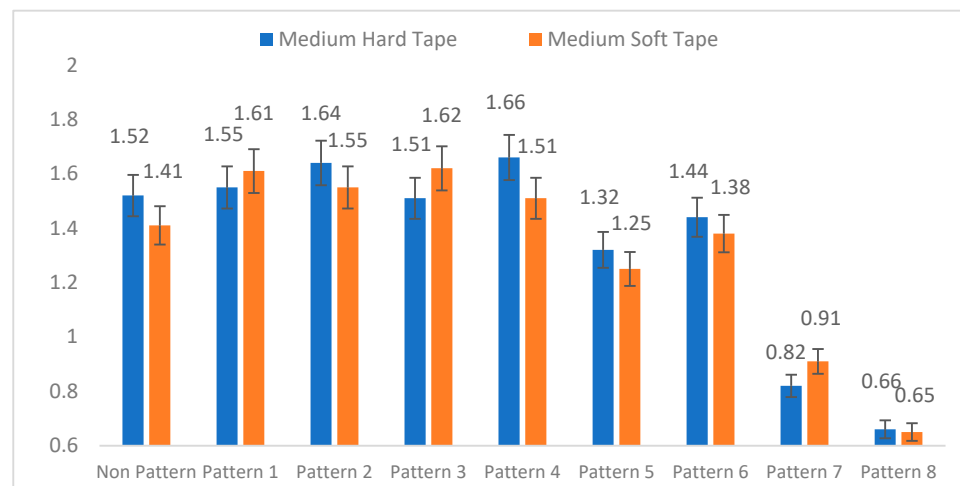


Figure 15. Printed solid ink density values.

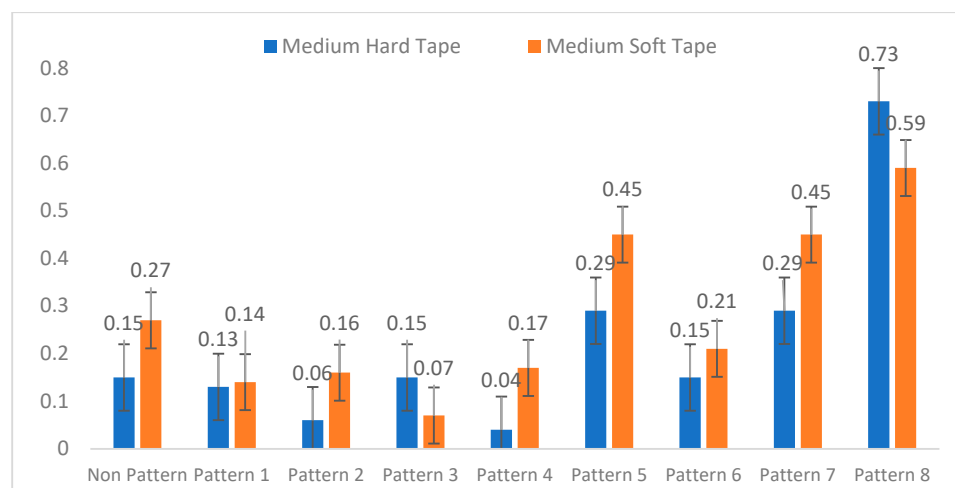


Figure 16. Graininess values.

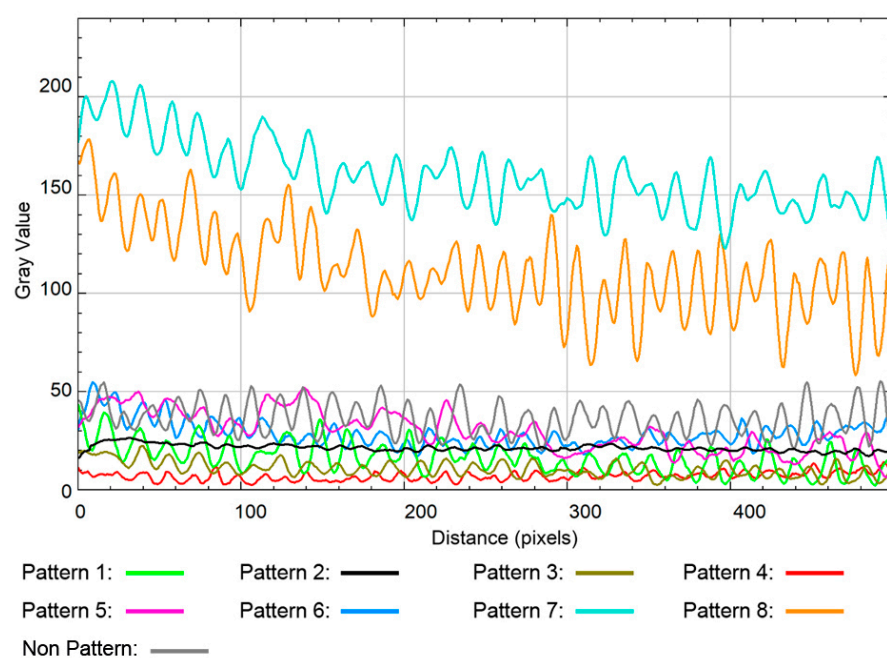


Figure 17. Graininess intensity for each pattern (medium-soft tape).

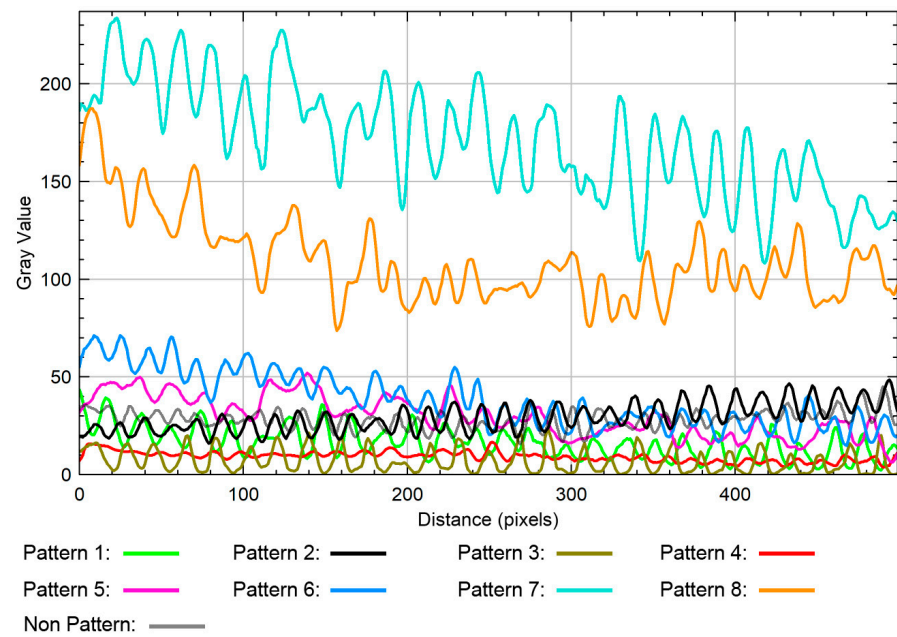


Figure 18. Graininess intensity for each pattern (medium-hard tape).

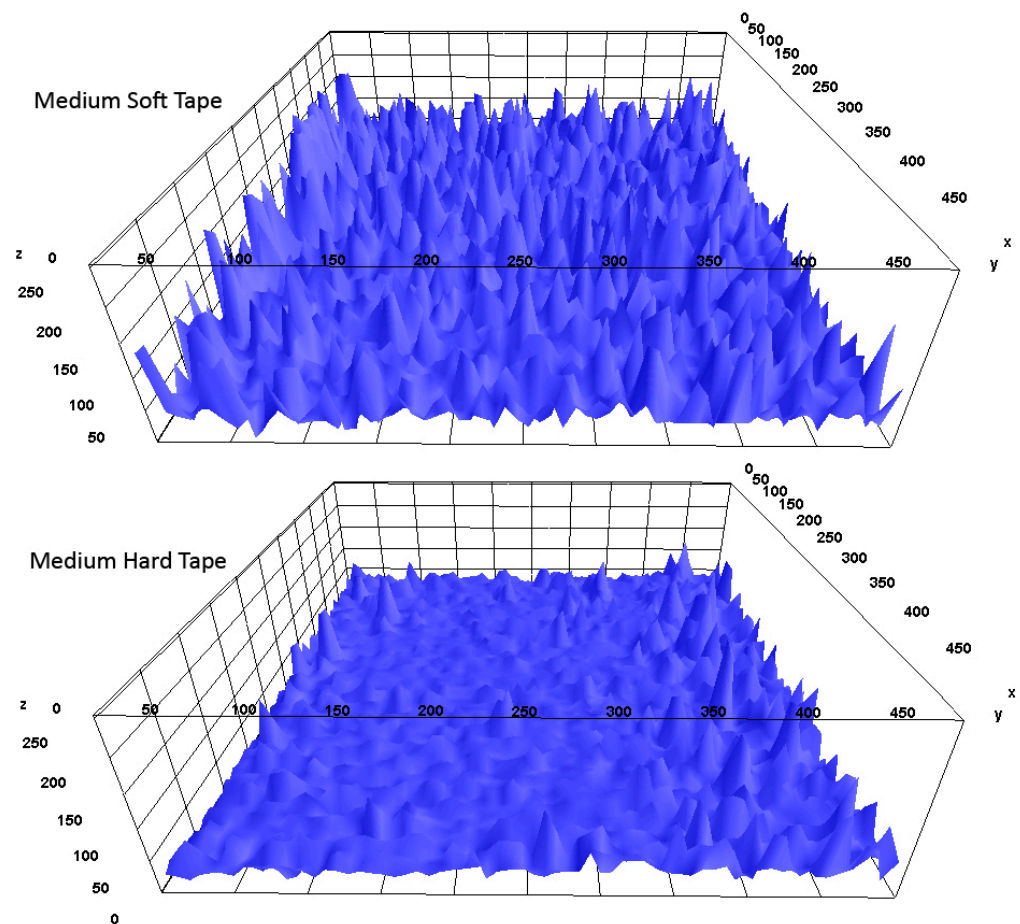


Figure 19. Non-pattern graininess analysis.

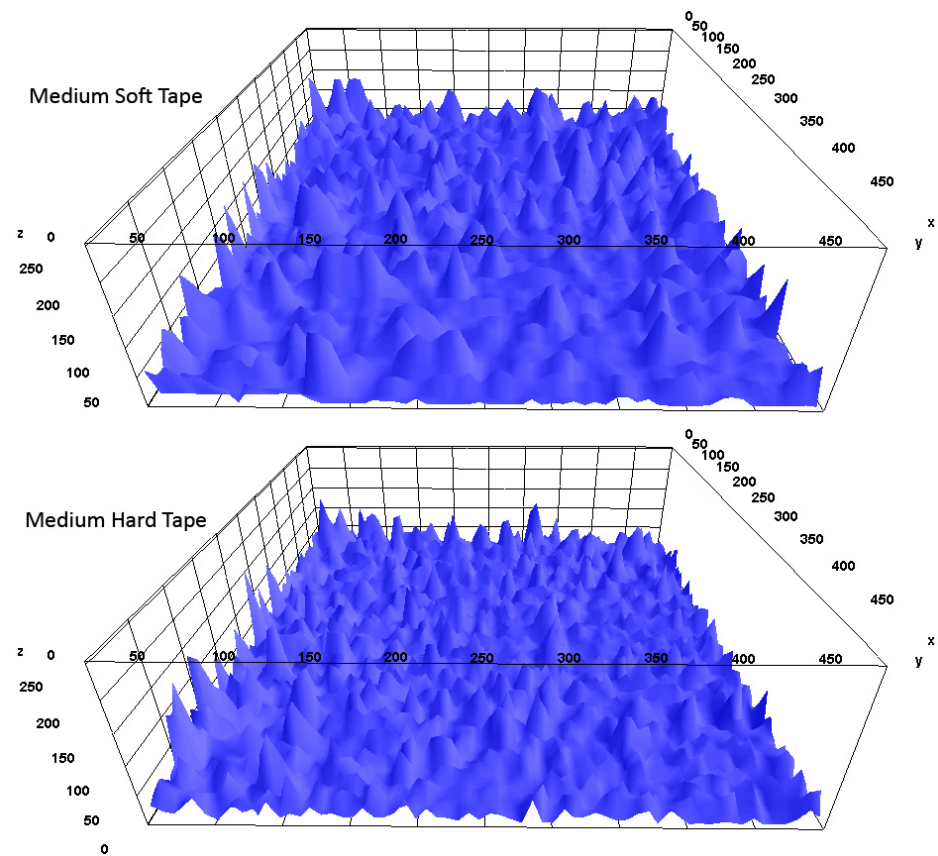


Figure 20. Pattern 1 graininess analysis.

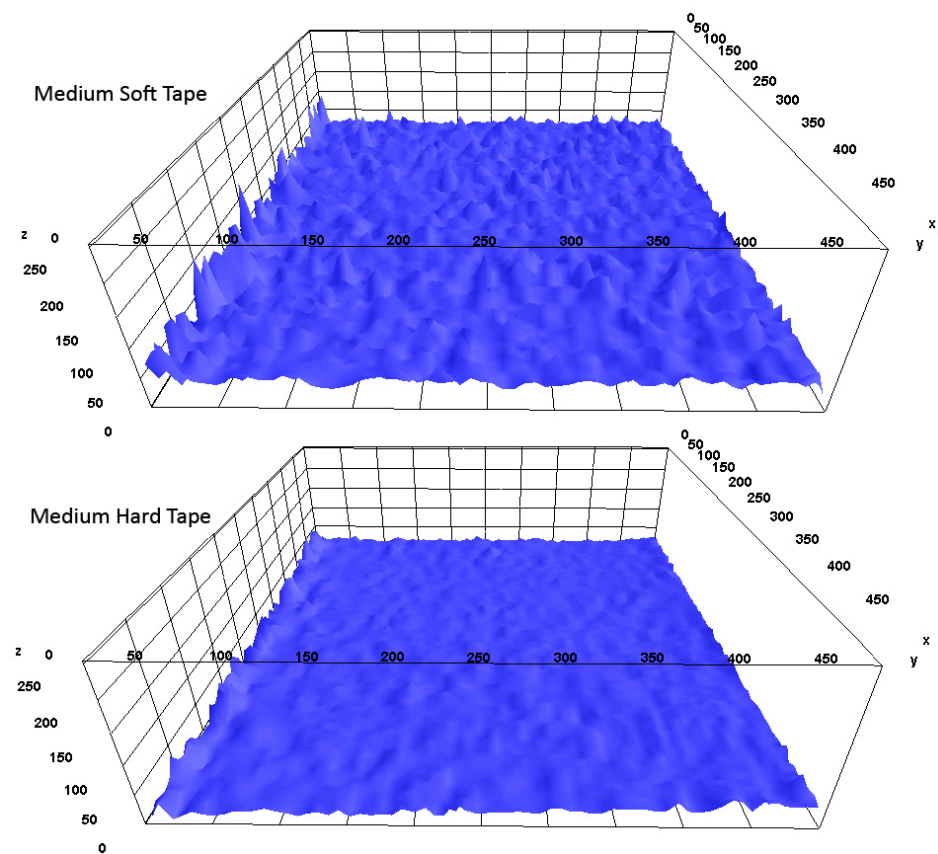


Figure 21. Pattern 2 graininess analysis.

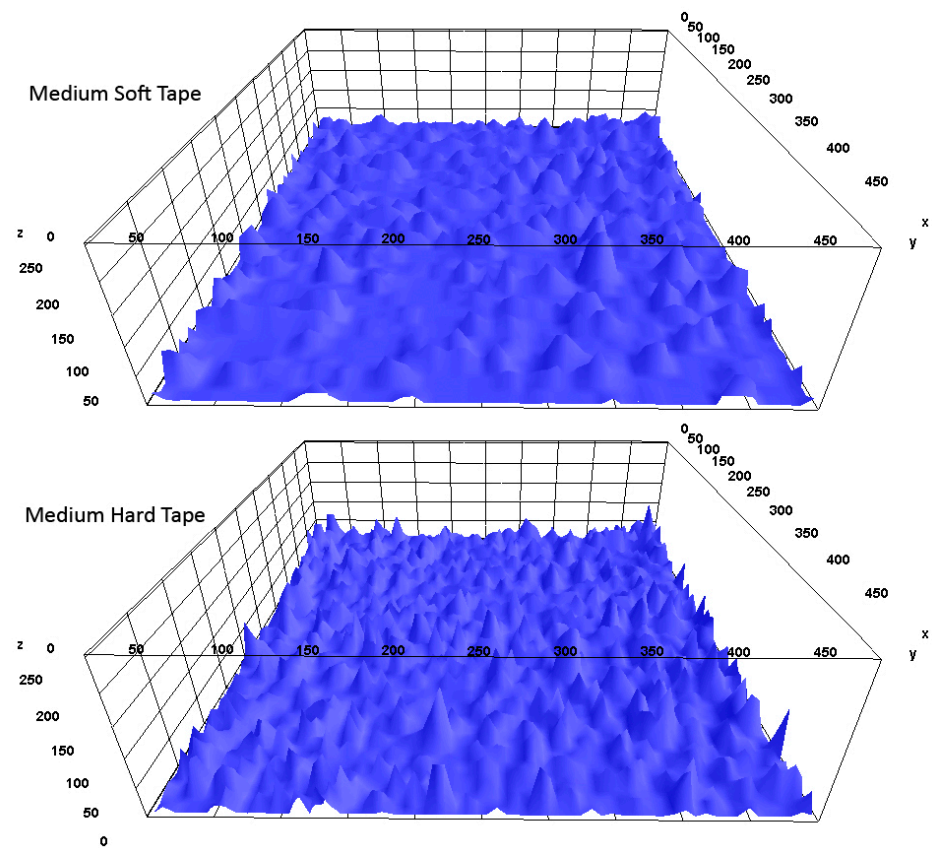


Figure 22. Pattern 3 graininess analysis.

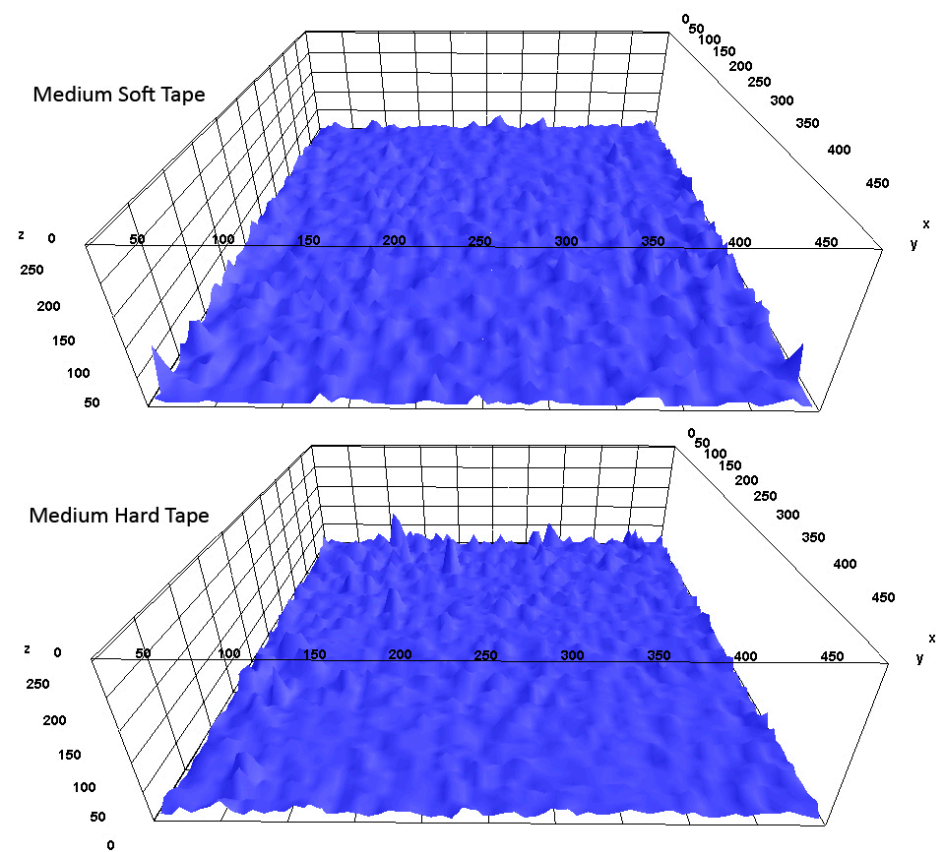


Figure 23. Pattern 4 graininess analysis.

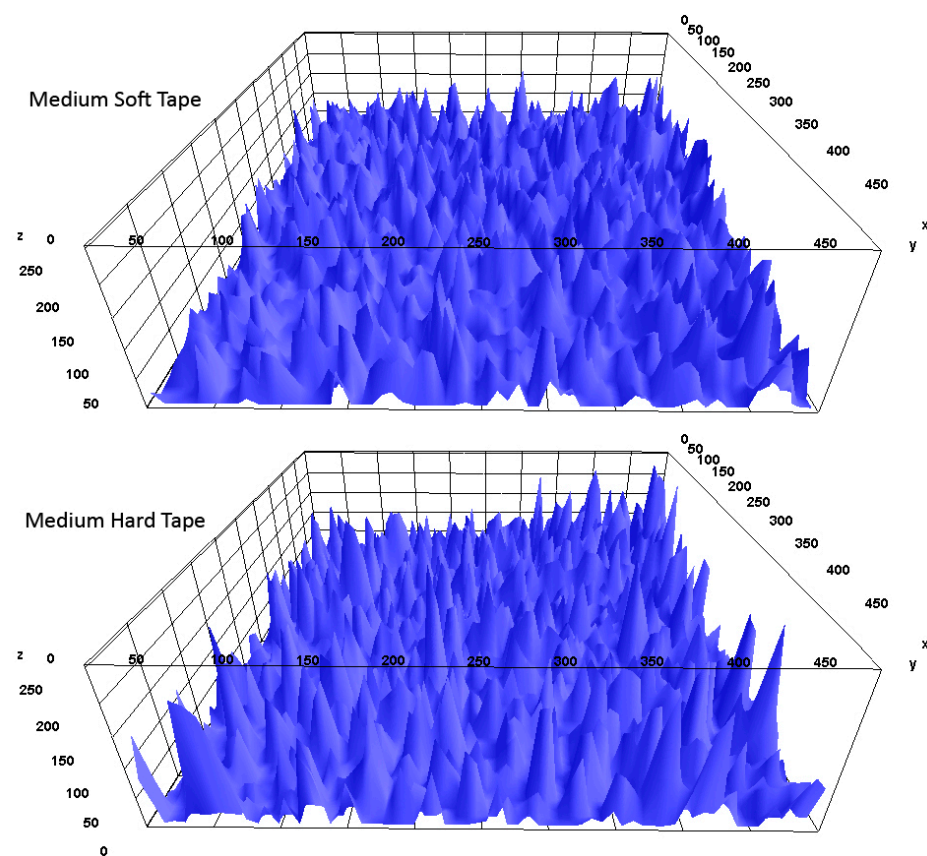


Figure 24. Pattern 5 graininess analysis.

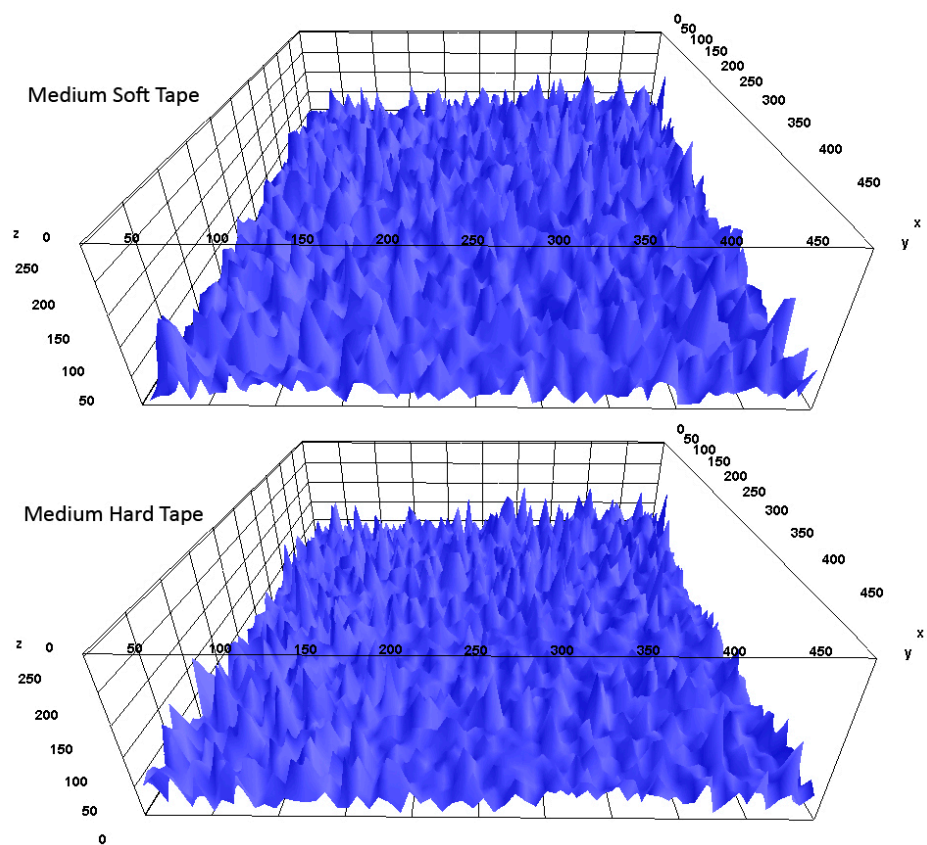


Figure 25. Pattern 6 graininess analysis.

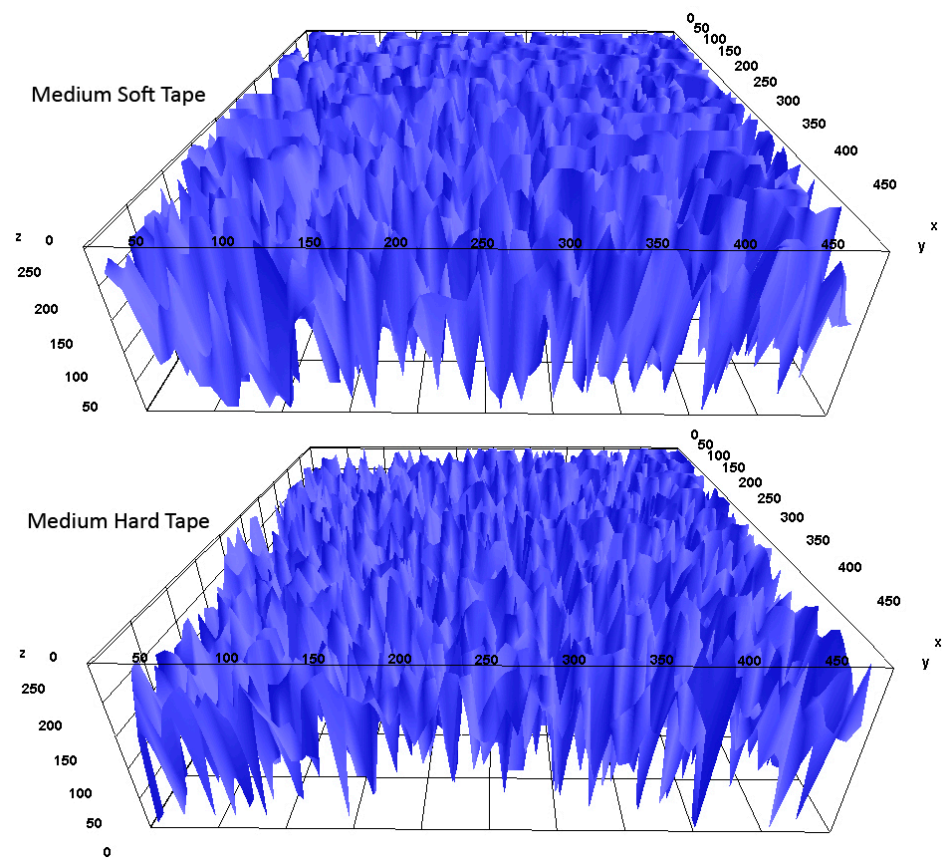


Figure 26. Pattern 7 graininess analysis.

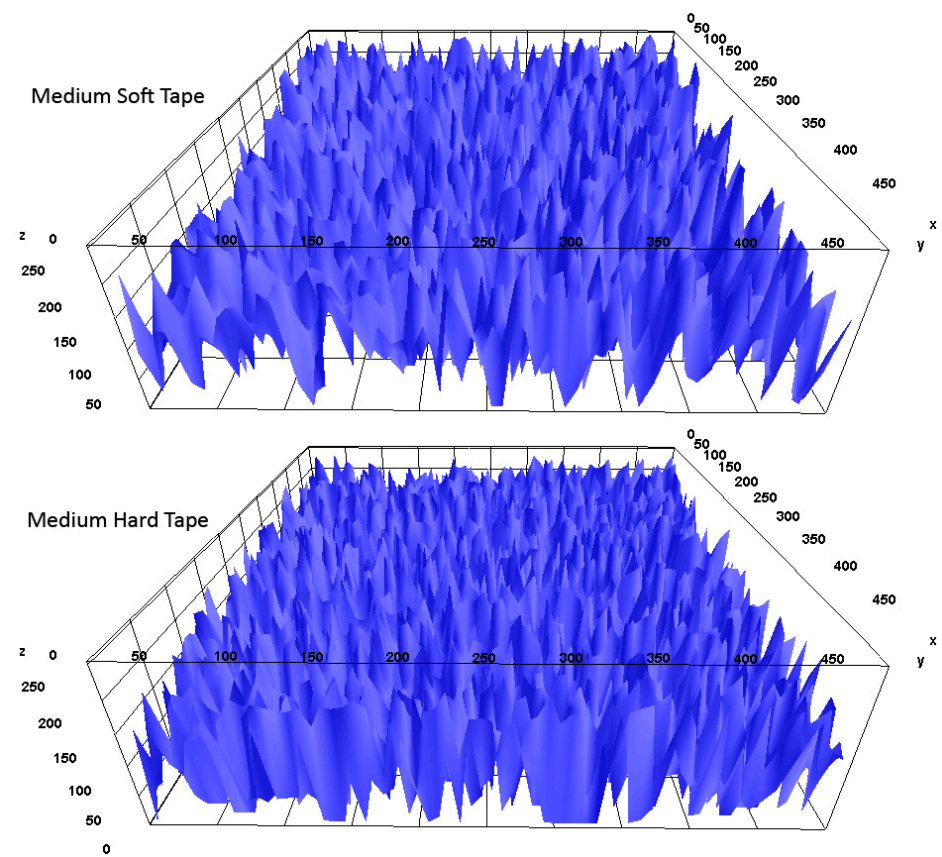


Figure 27. Pattern 8 graininess analysis.

On the other hand, the visual results of the print results provide insight. Here, solid smoothness cannot be achieved on the surface on which no micro-pattern is applied, and also trail edge voids are observed (Figure 28).

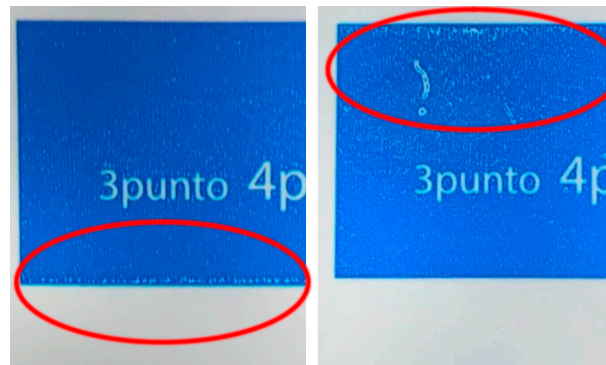


Figure 28. Trail edge voids—no pattern applied. The mounting tape used was medium-hard on the left and medium-soft on the right.

The most successful solid edge from the eight different patterns prepared is Pattern 4. SID is the highest, and graininess is the lowest. In addition, there are no gaps on the solid edges (Figure 29).

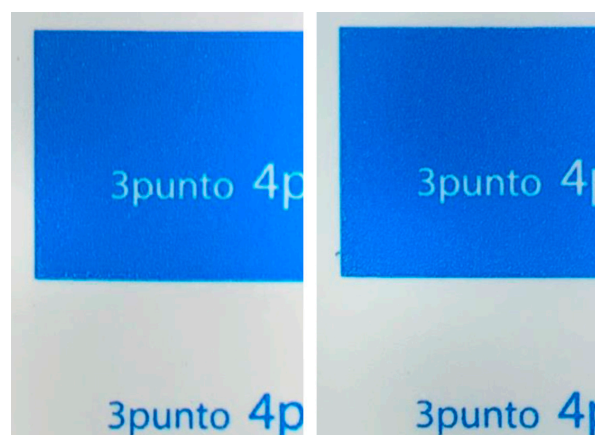


Figure 29. No trail edge voids are observed. The mounting tape used is medium hard on the left and medium soft on the right.

4. Conclusions

As a result of all the examinations, significant differences were detected when the prints made without micro-pattern and with micro-patterns were examined. It has been observed that the ink cannot be transferred completely in areas without micro-patterns, while in areas with micro-patterns, the pattern ratio per unit area seriously affects the ink transfer.

In areas without micro-patterns, ink laydown is not fully successful because the ink accumulates on the plate but is not transferred well to the substrate. With the developed micro-patterns, trail edge voids in the solid areas and the ink accumulation edge of the screen dots are eliminated. Ink is distributed more homogeneously without graininess. It has been determined that this results in a more stable measurement of SID and eliminates the measurement of grainy solids and low SID.

In these micro-pattern studies, the best results in homogeneous laydown of ink transfer on the substrate were obtained with a micro-pattern that is filled with at least 50% of the unit area. If the micro-pattern ratio per unit area increases, it resembles a non-pattern

structure. When the micropattern per unit area is applied at less than 50%, ink transfer decreases, SID drops, and ink laydown worsens.

This study has shown that reducing the cell volume of the anilox roller allows us to obtain a more uniform ink laydown with less ink on the corresponding micro-pattern.

According to Deganello, thinner lines offer the best height/width ratio, producing networks with better conductivity, clearly demonstrating the feasibility and value of flexographic processing using micropatterning of conductive structures [25].

This study was tested in the narrow web flexo. It is especially used in small-size packaging and label printing. This research is going to provide a solution for better ink transfer with plastic substrates for narrow web applications.

Author Contributions: Conceptualization, N.K.; Formal analysis, T.S.; Investigation, N.K.; Writing—original draft, N.K.; Writing—review & editing, T.S.; Funding acquisition, N.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

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