Analysis of Dot Gain Produced by Interactions of Flexographic Plate and Anilox Roll Screen Frequencies

Ramesh R. Dendge

Government Institute of Printing Technology, Mumbai, India
c. a. rameshdendge@rediffmail.com

Abstract

Flexography prints on non-absorbent as well as absorbent substrates using liquid ink. With developments in photopolymer plate and anilox roll manufacturing technology, we can print half tone with screen frequencies exceeding 150 LPI (Lines per Inch) where the print quality can be comparable with offset printing results. This has helped flexographic printer to reproduce the black-and-white, single colour tone and full colour graphic original, satisfying the printing and packaging needs of many customers. But unlike other printing technologies in flexographic printing screen frequency of plate i.e. image carrier and engraving line frequency of anilox roll collectively affect the smoothness and uniformity of reproduced half tone image. Furthermore, the LPI of the screen used in plate making also adds to variation in tonal reproduction. In the presented work 3 line frequencies expressed in CPI (Cells per Inch) of anilox roll and 5 screen frequency of image carrier are selected and their effect on print characteristics is studied using the plot of theoretical dot area against apparent dot area. Given the sizable capital investment involved in manufacturing of anilox roll, this work is directed at finding the optimum combination of screen frequency and line frequency required to achieve tonal balance.

Keywords: Half Tone Screen Frequency, Dot Area, Dot Gain, Anilox Roll Line Frequency, and Dot Gain Curve.

1. INTRODUCTION

Flexography's application area label, flexible and rigid package printing and industrial printing application areas. Flexography as a printing technology reproduces colour in line and half-tone form. It is capable of producing half tone print at screen frequency i.e. LPI (Lines per Inch) of 150 and above [1]. It represents 75% of the $440 billion printed packaging market. 92% of its global volume is packaging, with 8% divided among pharmaceutical, security printing, printed electronics and similar markets [2].

In flexography ink transfer and print quality is controlled by an anilox roll that transfers ink to half tone image on a flexographic image carrier i.e., plate. The anilox roll has a helical row of tiny cells engraved at regular spacing and angle. The fineness of an anilox roll is defined by a number of engraved cells per linear inch often called line frequency expressed in CPI. Therefore, the regular geometrical patterns of half tone image screen frequency in question and the anilox roll of identified line frequency interact with each other and decides the ultimate half tone print quality of half tone and process colour flexographic printing [3]. The screen frequencies employed in a label, flexible and rigid package printing and industrial printing applications are 55, 65, 70, 85, 100, 120, 133, and 150 with increasing screen frequency officering smoothened print. The line frequencies of anilox roll available range between 250 and 1200 [3]-[4].

The flexographic printers follow the industry standard that the line frequency of anilox roll should be at least 3- 4 times that of printing plate screen frequency so that 3% half tone dot can be printed. Even in some situations printers maintain this ratio at 4 - 5. With this yardstick printer for a screen frequency of 70 LPI can select an anilox roll line frequency between 280 and 550 CPI [5]. Of course, the print requirement of the smallest halt tone dot area demands a finer anilox roll but still, the printer has a choice of anilox line frequencies. Therefore printer is required to keep an inventory of anilox roll with multiple line frequency for the intended screen frequency. The anilox roll being the costliest part of the flexographic printing unit; for small and medium scale printers this requirement adds to the procurement and carrying cost of the anilox roll inventory. This general situation prevails in the label, flexible and rigid package printing and industrial printing application areas of flexography. The use of reduced anilox inventory has other advantages like the benefit of independence on the supplier for providing specific type roll, less lead time in case of breakdown, less storage space required to maintain inventory, no more downtime in changing the anilox roll at the time of change in product or application, improved productivity, reduction in consumption of cleaning solvents used during each changeover and reduced operating cost.

The tiny cells are engraved at 30^0, 45^0, 60^0, and 90^0 angles to the axis of the metallic anilox roll. The hexagonal cell geometry engraved at 60^0 increases the resolution of the anilox roll and is widely used in flexographic printing. The ink storage capacity of an anilox roll is expressed in BCM (Billion Cubic Micron) per square inch of engraved surface. Typical values of anilox roll ink volume range from 9-4 BCM for heavy lines and solids to 2.8 to 0.9 for process colour printing [5]. Higher volume translates to higher solid ink density, more colour or a heavier coating thickness. Lower volumes apply thinner ink films directly associated with higher print quality and process efficiency. The higher the line frequency of the anilox roll the lower its ink volume and vice versa. Multiple choices of anilox roll line frequencies for a given half tone print resolution i.e., screen frequency can result in the use of anilox roll with too low or too high line frequencies and limits print quality in half tone printing. The printing troubles arising on account of the use of anilox roll with too low line frequency are bleeding-smudging, blocking, bridging, ink build up on edges of the image, halo effect or squeezed edges on the half tone dot moiré effect, High color strength. On the other side too high line frequency results in a transfer of lower ink volume ghosting effect low colour strength [6]. It is also observed that the higher line screen anilox rollers tend to become more clogged more and lose their advantage of introducing higher LPI counts if not cleaned properly [7].

The proposed work involves identifying an anilox roll line frequency that is capable of half tone printing at different screen frequencies leading to a reduction in inventory of anilox rolls with varying line frequencies. Half tone printing performance in term of characteristics curves is compared for variation at identified anilox roll. The anilox roll line frequency showing overlapping or close characteristics curves with reduced dot gain can be preferred over others. This systematic approach eliminates the reliance on industry standard of selecting anilox roll line frequency with 4- 5 multiple of screen frequency and the need of maintaining inventory of multiple anilox line frequencies.

At present, the selection of anilox rolls during half tone printing for various applications is governed by industry standard recommendations given by technical services of anilox roll manufacturers. Such recommendations presented in terms of the range of multiplying factors to get anilox roll line frequency from a given screen frequency are observed to take place from 3 to 5.5. The approach of plotting characteristics curves, a useful element in describing half tone print performance, has been used in identifying common screen angles for multiple screen frequencies involved in half tone screen printing. This approach provided a tool to reduce secondary moiré problems in printing [8]. The characteristics curve is largely used in colour control during lithographic offset printing in process optimization and identification of significant variables. Also, the effects of laser engraving settings on etch depth of polymer clichés was carried out for different screen frequency and screen angles to study pad printing quality [9]. But the application of such a subjective approach in identifying an anilox rolls line frequency that can accommodate has not been suggested by authors and anilox roll manufacturers.

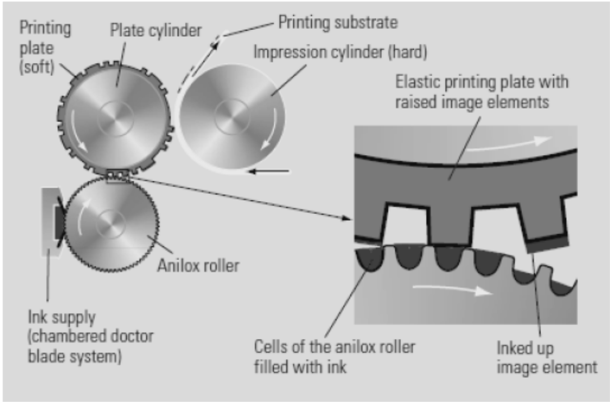

Figure 1: Flexographic printing unit

2. FLEXOGRAPHIC PRINTING TECHNOLOGY

The printing unit of the flexographic press and principle is shown in figure 1 and 2. The flexographic press is a roll-to-roll, direct rotary technology using wrong-reading flexible relief image carriers called plate. The inking system of the flexographic printing unit consists of an ink fountain and an anilox roll. The anilox roll has a pattern introduced by engraving on its surface to hold and transfer ink to the substrate in question. The structure of the anilox roll surface is shown in figure 2. Anilox roll is a mild steel cylinder with a finely engraved chromium or ceramic surface and is dipped in the ink reservoir. During inking the excess ink is scraped off the surface of the anilox troll by a metallic doctor blade [9]. The resolution of anilox engraving is expressed in cells per linear inch i.e. CPI. The ink from anilox is received by the relief parts, that is, image areas of the plate and finally transferred onto the substrate producing print. Flexographic printing technology uses liquid ink with a viscosity range of 50-500 mPas and offers an ink film thickness of 10-15 microns [10].

The remaining paper is structured to discuss the materials, parameters and required trials run in section 3, results and discussion is considered in section 4. Identified conclusions are communicated in section 5.

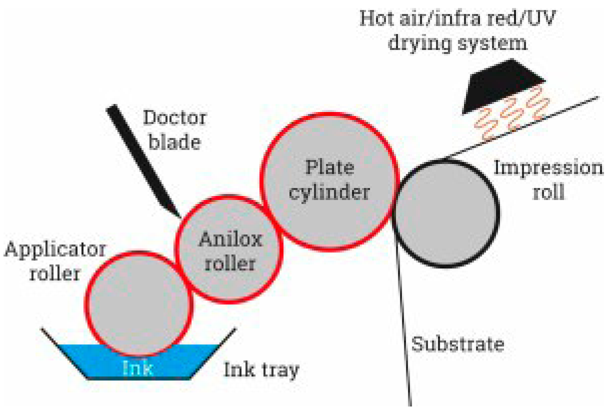

Figure 2: Flexographic printing Working Principle

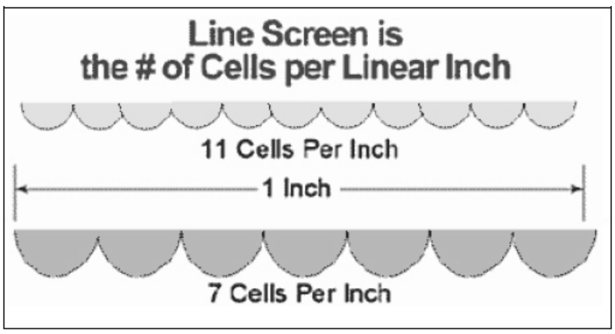

Figure 3: Cross Section of Anilox Roll

3. Materials and Parameters

The experimental set up includes varying and constant parameters as stated in tables 1 and 2.

Table 1: Varying Parameters

Parameter	Variable
Screen Frequency (LPI)	55, 70, 85, 100, 133
Anilox Line Frequency (CPI)	500, 700, 1000

Table 2: Constant Parameters

Parameter	Constant
Printing Speed (m/min)	80.00
Substrate	110 GSM Art Paper
Printing Ink	Seigwerk k UV Ink
Half tone dot shape	Round
Anilox Roll Angle and Volume (BCM)	60^0 2.8-0.9

The experimental model chosen covers a total of 15 trials. The printing was carried out on a narrow web flexographic printing machine. Fifty sheets were printed for each trial with strict control keeping over constant parameters. The response variable identified is the dot area of each gradation expressed in percentage.

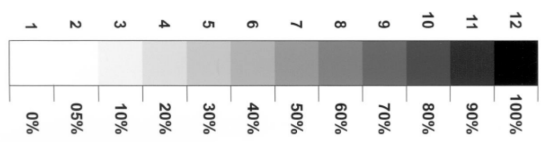

Figure 4: 12-Half Tone Step Gray Scale

The test image identified for printing 15 trials as designed above has combined five half tone grey scales of five screen frequencies and three anilox roll engraving frequencies as shown in table 1. The grayscale helps facilitate the measurement of the dot area of each tone gradation from each trial print using an electronic densitometer. The test image as used in the trials is shown in figure 3. During the measurement of percentage dot area five random prints of each trial were selected as samples wherein each sheet i. e. sample involved dot area measurement of 180 half tone steps. A round dot shape is typically used to counter the possibility of high dot gain [11]. The parameters shown in table 2 are process variables capable of affecting print quality and are held constant to get characteristics curve plots giving performance relationship between screen and anilox roll line frequency. The substrates have different ink absorption rates and give different ink film thicknesses. UV (Ultraviolet) inks have high colour strength with workable viscosity as that of water- and solvent-based inks [12]. Dot area measurement is carried out with a SpectroEye photodensitometer with D50 illuminant, 10^0 observer angle, density standard T, and 45:0 measuring geometry setting. 10^0 observer angle was preferred to 2^0 for a wider area of view in the blue-green region of the spectrum. A standard calibration and operating procedure is followed during measurement. All measurements yielded 150 readings as data to be processed for getting information about dot gain.

4. RESULT AND DISCUSSION

150 gradations from 15 trials printed with offset press used for measurement of the response variable that is dot area percentage from individual grey scale wedge for all combinations of screen frequencies (LPI) and anilox screen rulings (CPI). the percentage dot area values were calculated. The observed dot area and absolute dot gain values are tabulated for anilox rolls of 500, 700 and 1000 lines per inch with screen frequencies of 55, 70, 85, 100 and 133 LPI in appendices 1 and 2 respectively. Graphs are plotted with data tabulated in appendices 1 and 2. Figures 5, 6 and 7 show the percentage dot area curves, which is the tonal curves of the prints at various screen frequencies for the anilox roll line frequencies of 500, 700 and 1000 lines per inch. In these graphs x- and y- axes are represented by theoretical dot area (%) and observed area on print (%) respectively. Similarly, figures 8, 9 and 10 show the absolute dot gain curves at anilox roll line frequencies of 500, 700 and 1000 lines per inch. In these graphs x- and y- axes are represented by theoretical dot area (%) and calculated absolute dot gain respectively

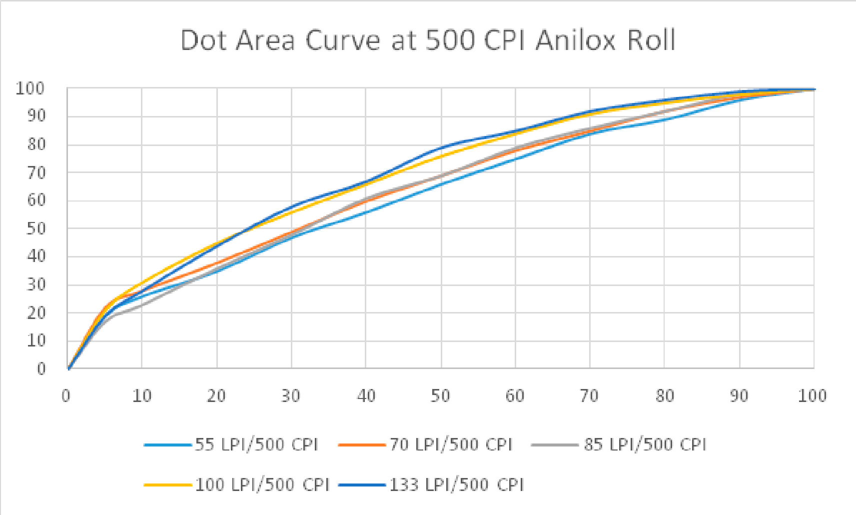

Figure 5: Dot Gain curve for Anilox Roll Line Counts at 55 LPI

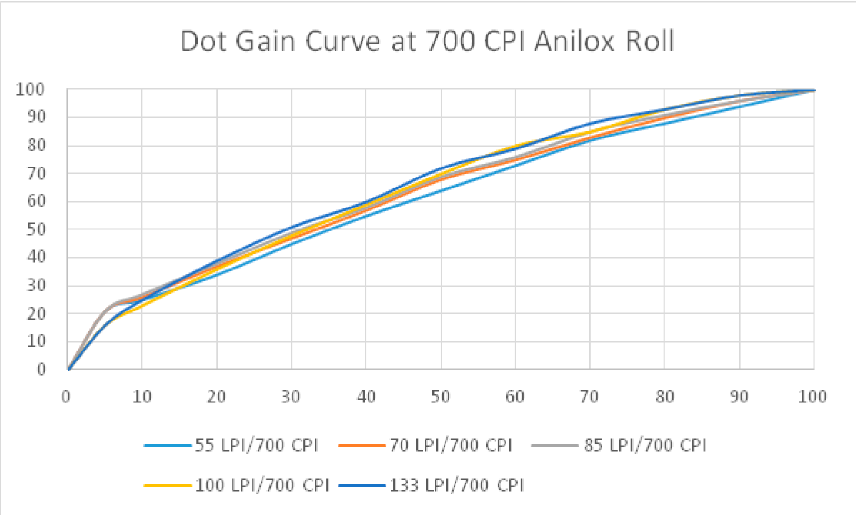

Figure 6: Characteristics curve for Anilox Roll Line Counts at 70 LPI

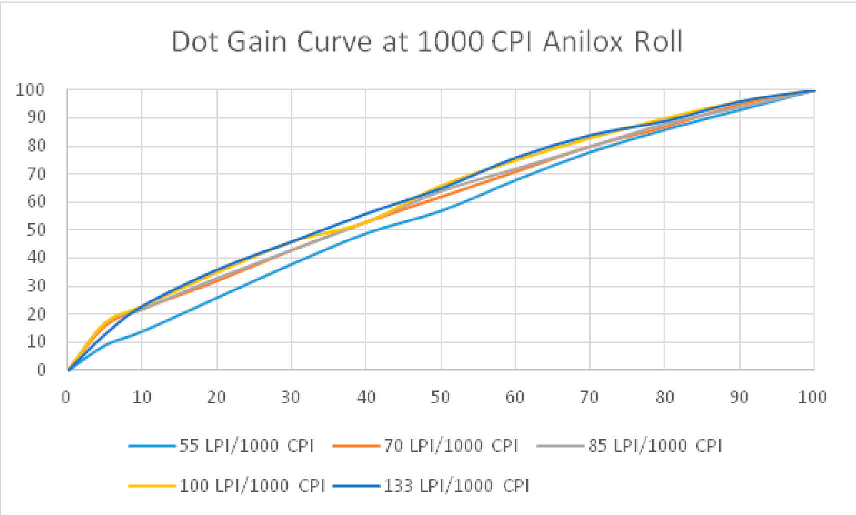

Figure 7: Characteristics curve for Anilox Roll Line Counts at 85 LPI

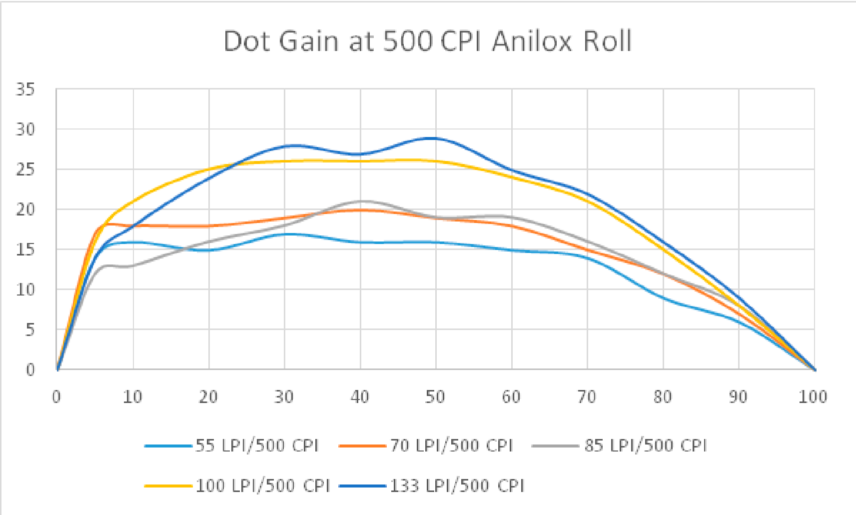

Figure 8: Characteristics curve for Anilox Roll Line Counts at 100LPI

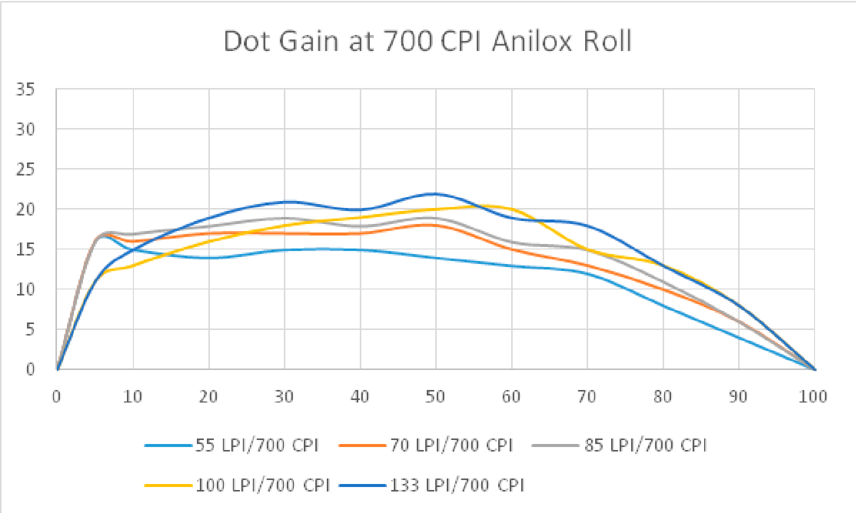

Figure 9: Characteristics curve for Anilox Roll Line Counts at 133 LPI

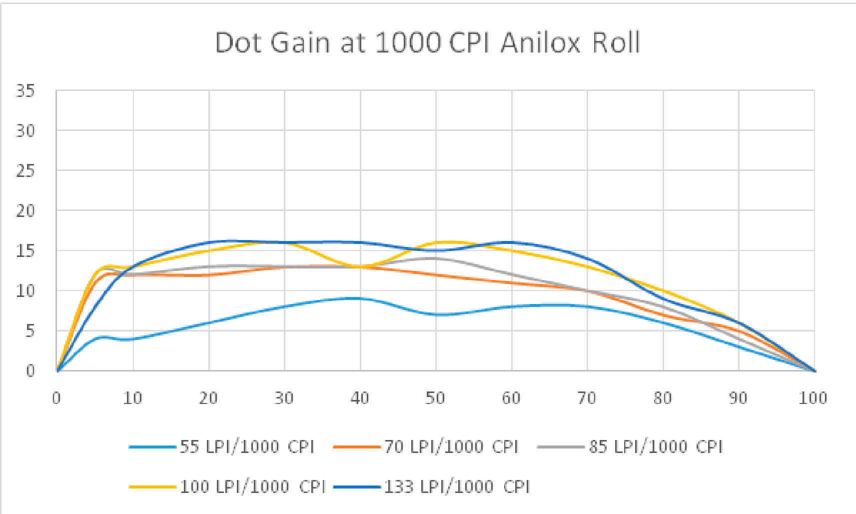

Figure 10: Characteristics curve for Anilox Roll Line Counts at 133 LPI

Figures 5 to 10 show that at the same anilox frequency, the absolute dot gain increases with screen ruling (LPI). Therefore, in these trials screen, the ruling of 133 LPI is showing the maximum whereas the 55 LPI is the minimum dot gain. Also, absolute dot gain decreases with increasing anilox frequency if the screen ruling is held constant. This behaviour is observed with print i.e. screen frequencies 55, 70, 85, 100 and 133.

Also, figures 5 to 10 suggest that the absolute dot gain is not varying much for 70, 85, 100 and 133 LPI for anilox frequencies as corresponding plots in figures 8, 9 and 10 show that except 55 LPI screen curves of 70, 85, 100 and 133 LPI appear comparatively closer at higher anilox frequency that is 100 CPI. At 500 CPI the behaviour of dot gain curves plotted for 50, 70, 85, 100 and 133 LPI are different, in this case, they are clearly distinct. In the case of anilox frequency 700 CPI the dot gain curves plotted for 50, 70, 85, 100 and 133 LPI appear to be a little closer. The Anilox Line Frequency to Screen Ruling ratio for 55, 0, 85, 100 and 133 screen rulings and 500, 700 and 1000 CPI is shown in table 3 below. As compared to table 1 of ISO 12647-6:2020 instead of the tone values on the printing form the value on the printed sheet are measured for 55, 70, 85, 100 and 133 LPI and the dot gain values are observed to be +/- 2 and +/- 3 for ruling up to 120 LPI and above 120 LPI respectively. Furthermore, measurement condition is kept uniform and measured tone values are considered for results and discussion. As per ISO 12647-6:2020 recommendation. No measurement of tone values on the printing plate is carried out.

Table 3: CPI to LPI Ratio

Anilox Frequency (CPI)	Screen Ruling (LPI)				
	55	70	85	100	133
500	9.09	7.14	5.88	5.00	3.75
700	12.72	10.00	8.23	7.00	5.26
1000	18.18	14.28	11.76	0.00	7.52

5. CONCLUSION

It can be concluded from these trials that in flexographic halftone printing the dot gain increases with increasing screen frequency and decreasing anilox roll line frequency. The anilox frequency is responded to clearly by the lower and higher screen rulings. Hence, selecting one anilox roll line frequency for multiple screen frequencies that optimizes that tonal loss in half tone printing remains the best alternative for the flexographic printer.

The dot gain curves at a given anilox frequency show the same pattern that a higher CPI:LPI ration produces the minimum dot gain and vice versa, but these ratios offer many distinct values and suggest irregular deviation among the dot gain curves. Also, the extreme LPIs behave differently but the middle three LPIs offer comparable performance in terms of dot gain as compared to the lowest and the highest LPIs that any printer handle. Though the selection of an anilox roll having a higher CPI count is always useful, the economy is also one of the important factor. Industrial houses associated with the manufacturing of anilox roll have proposed different anilox roll frequency-to-LPI ratio for flexographic printers which varies between 4 and 6 instead of one anilox engraving frequency for the printer. Besides this significant variation in anilox frequency variation; the flexographic printers also have to consider the customer requirement of minimum reproducible dot percentage on print. A flexographic printer is, therefore, required to keep cell opening smaller than the minimum reproducible plate dot, and such a situation will demand more finer anilox roll. In identifying an anilox roll that matches with the plate LPI printer may invariably end up using too finer an anilox roll. Such instances can increase the possibility of an inventory which is more than required and blocking of funds. This experiment has helped flexographic printer to optimize both engraving frequency and reproducible LPI.

6. FUTURE SCOPE

The CPI:LPI ratio as a guide to select the anilox roll for a screen frequency in question is actually a recommended value and every printer selects an anilox roll as per the economy he can afford to keep customer requirements in mind. There cannot be the best CPI:LPI ratio in flexographic printing instead there is a range of anilox roll frequencies that printer can select from. Another issue that printer can face in flexography is the secondary or tertiary moire because of an anilox roll patterned surface. Besides flexography, screen printing also shows problems of secondary and tertiary moire because of pattern of screen mesh. This more problem can occur with both single-color half tone and process colour printing.

This work can be extended to design an experiment to optimize screen angle for half tone printing in flexography that involve the use of multiple anilox roll and screen frequencies.

Appendix A

Theoretical Dot Area	55 LPI/500 CPI	55 LPI/700 CPI	55 LPI/1000 CPI	70 LPI/500 CPI	70 LPI/700 CPI	70 LPI/1000 CPI	85 LPI/500 CPI	85 LPI/700 CPI	85 LPI/1000 CPI	100 LPI/500 CPI	100 LPI/700 CPI	100 LPI/1000 CPI	133 LPI/500 CPI	133 LPI/700 CPI	133 LPI/1000 CPI
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	19	21	9	22	21	16	17	21	17	21	16	17	19	16	13
10	26	25	14	28	26	22	23	27	22	31	23	23	28	25	23
20	35	34	26	38	37	32	36	38	33	45	36	35	44	39	36
30	47	45	38	49	47	43	48	49	43	56	48	46	58	51	46
40	56	55	49	60	57	53	61	58	53	66	59	53	67	60	56
50	66	64	57	69	68	62	69	69	64	76	70	66	79	72	65
60	75	73	68	78	75	71	79	76	72	84	80	75	85	79	76
70	84	82	78	85	83	80	86	85	80	91	85	83	92	88	84
80	89	88	86	92	90	87	92	91	88	95	93	90	96	93	89
90	96	94	93	97	96	95	98	96	94	98	98	96	99	98	96
100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Appendix B

Theoretical Dot Area	55 LPI/500 CPI	55 LPI/700 CPI	55 LPI/1000 CPI	70 LPI/500 CPI	70 LPI/700 CPI	70 LPI/1000 CPI	85 LPI/500 CPI	85 LPI/700 CPI	85 LPI/1000 CPI	100 LPI/500 CPI	100 LPI/700 CPI	100 LPI/1000 CPI	133 LPI/500 CPI	133 LPI/700 CPI	133 LPI/1000 CPI
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	14	16	4	17	16	11	12	16	12	16	11	12	14	11	8
10	16	15	4	18	16	12	13	17	12	21	13	13	18	15	13
20	15	14	6	18	17	12	16	18	13	25	16	15	24	19	16
30	17	15	8	19	17	13	18	19	13	26	18	16	28	21	16
40	16	15	9	20	17	13	21	18	13	26	19	13	27	20	16
50	16	14	7	19	18	12	19	19	14	26	20	16	29	22	15
60	15	13	8	18	15	11	19	16	12	24	20	15	25	19	16
70	14	12	8	15	13	10	16	15	10	21	15	13	22	18	14
80	9	8	6	12	10	7	12	11	8	15	13	10	16	13	9
90	6	4	3	7	6	5	8	6	4	8	8	6	9	8	6
100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

7. REFERENCES

[1] J. M. Adams et al, “Flexographic Printing,” in Printing Technology, 4th Ed. New York: Delmar, 1996 ch.17, pp. 455-459.

[2] J. Tuccitto et al, “Flexographic Market Segments,” in Flexography Principles and Practices, 6th Ed. New York: Foundation of Flexographic Technical Association, 2013, ch.2, pp. 31.

[3] F. N. Siconlfi et al, “Introduction to Flexography,” in Flexography Principles and Practices, 4th Ed. New York: Foundation of Flexographic Technical Association, 1992, ch.1, pp. 1-6.

[4] F. N. Siconlfi et al, “Introduction,” in Flexography Principles and Practices, 4th Ed. New York: Foundation of Flexographic Technical Association, 1992, ch.10, pp. 219-224.

[5] J. P. Trungale, “Selecting Anilox Rolls,” in The Anilox Roll Heart of the Flexo Process, Ed. New York: Jelmar, 1997, ch. 10, pp. 91-99.

[6] M. Hornschuh, “Ghosting- a typical flexo phenomenon?” Flexo Gravure Global, E-14009., vol. 18, pp. 8-11, February 2012.

[7] A. Savickas et al, “Assessment of the Condition of Anilox Rollers” Coatings MDPI 2021, 11, 1301.

[8] R. Dendge, “Minimizing the print quality limitations imposed by ISO screen angle choice when eliminating secondary moiré in monochrome halftone priting”, J.Print Media Technol. Res. iarigai, vol. 2, No (1- 61), pp. 29-37, March 2013.

[9] R. Xu, et al, “The effects of laser engraving settings on etch depth of polymer clichés and pad priting quality,” J.Print Media Technol. Res. iarigai, vol. 2, No (1-61), pp. papers 29-35, March 2013.

[10] H. Kipphan, “Flexographic Printing,” in Handbook of Print Media, Ed. New York: Delmar, 2000, ch.1, sec.1.3, pp. 46-48.

[11] A. Lorenz, et al, “Flexographic Printing High throughput technology for fine line seed layer printing on silicon solar cells,” 28 th Euro. Conf. PV Solar Energy Conf. 2013.

[12] K. Tritton, “Controlling the print characteristics,” in Color control in lithography, Ed. Surrey, UK: Pira International, 1993, ch. 9, pp. 149.

[13] G. Harms, “A good choice promises success” Flexo Gravure Global, E-14009., vol. 19, pp. 6-7, December 2013.