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TECHNICAL WHITEPAPER

Ink Saving using Bellissima Screening

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June 2021

Version 1.0

Contents

1. About the Author

Wilbert Streefland, formally the Technical Development Manager at SCA, is the owner of Technology Coaching B.V. and is a specialist consultant for organizations driving developments in printing throughout the world.

2. Introduction

In this article, we will discuss a different source for dot gain by comparing conventional A(mplitude)M(odulated) halftone screens with different Hamillroad Bellissima (D)igitally (M)odulated screens and explore how this impacts ink consumption during printing.

To correctly investigate the source for dot gain, we change from using the word "Dot Gain" to "Contrast Gain".

The following two questions are the bases for designing a hypothesis and conducting tests:

- What are the sources for contrast gain?
- What are the benefits when changing from an AM halftone screen to a Bellissima halftone screen?

Textbooks in printing describe "Dot Gain" as the size of a printed dot being larger than the design size for that dot. The increase in dot size between the design dot size and the printed dot size is the dot gain.

To measure the dot gain, a densitometer - or better, a spectrophotometer is used. These instruments measure light reflection. Thus, the instrument is not measuring the physical size of a dot but the light reflected from a printed area. The difference in light reflected from a full tone area and an area constructed from dots, the so-called halftone area, is the contrast value.

The maximum difference in light reflected is the value measured on an unprinted area and a full tone area. We can call this "the full tone range". Using this full tone range and the reflectance value of a halftone area allows calculating the contrast value as a percentage of the full tone reflectance value.

A spectrophotometer measures the light reflectance value on pre-defined wavelength intervals between 400 and 700 nm, most commonly in intervals of 10 nm. From this spectral reflectance curve, the "L", "a", and "b" values can be calculated. For this work, we used the ASTM tables for light source: D65, angle 10°, and standard observer 1964, where: the "a" value represents an axis from Green (-a) to Red (+a), the "b" value represents an axis from Blue (-b) to Yellow (+b), and the "L" axis goes from 0 (Black) to 100 (white).

The delta E color difference between the two measurements with the spectrophotometer, e.g. full tone and halftone, can be calculated using the L, a, b values for that full tone and halftone area with the equation:

$$\Delta E = \sqrt{(L_{ref} - L_m)^2 + (a_{ref} - a_m)^2 + (b_{ref} - b_m)^2}$$

L_{ref} = L reference value

L_m = L measured value

a_{ref} = a reference value

a_m = a measured value

b_{ref} = b reference value

b_m = b measured value

The formula to do the relative contrast calculation can be based on using the delta E difference measured with a spectrophotometer between an unprinted and full tone area as tone range and the delta E between full tone and halftone area as contrast. The formula is as follows:

$$\%Contrast = \frac{100 * (\Delta E0\% - \Delta Ex\%)}{\Delta E0\%}$$

$\%Contrast$ = Contrast value

$\Delta E0\%$ = Delta E between 100% and 0%

$\Delta Ex\%$ = Delta E between 100% and x%

As already earlier expressed, we will not use the word "dot gain" but contrast and contrast gain.

This allows the use of any kind of halftone screen, not only a halftone screen constructed from dots where they are positioned in a fixed grid, expressed in line count, and the dot diameter changes in size. This is an Amplitude Modulated screen or AM screen. Other screens can be used for printing a halftone area that are not based on AM, for example, the Hamillroad Bellissima Digitally Modulated screen.

Any halftone screen used for printing a halftone area will have its own contrast gain (dot gain).

Let's look at possible sources for contrast gain.

1) Most flexo printing textbooks will still refer to dot deformation on the printing plates as the main source for contrast gain. But physically, it is not possible to deform a dot

on a printing plate to get to a contrast gain value commonly measured. It is very unlikely that dots on printing plates deform during printing. If dot deformation occurs on a printing plate, then the dot would also immediately damage due to the friction between printing plate and screen roll and/or printing plate and substrate. In flexo print, the operators are instructed to set the pressure between printing plate and screen roll, as well as between printing plate and substrate to" kiss touch", so how can a dot deform under those conditions resulting in gain?

2) Another more likely source for gain is that a printing element e.g. a dot, picks up more ink relative to a full tone area. This is a likely source for gain. It can be explained by looking at the surface energy and surface tension of ink and printing plate. These factors will result in more ink being transferred on the edges of a printed element compared to the centre of that element, depending on the ink type and the size of that element. Thus the larger the element, the lower the impact of the edge on the total ink transfer of that element. To illustrate: a 100 cm^2 area covered with 50 % of small dots is likely to transfer more ink than a full tone area of 50 cm^2.

3) And then, we have a further source for contrast gain; this is the light reflection/absorption by a printed element itself. Different halftone screens are likely to reflect/absorb light more or less efficiently. One could explain this as an "edge effect"; light reflection/scattering on the edge of an element is likely to be different from that in the centre of the same element.

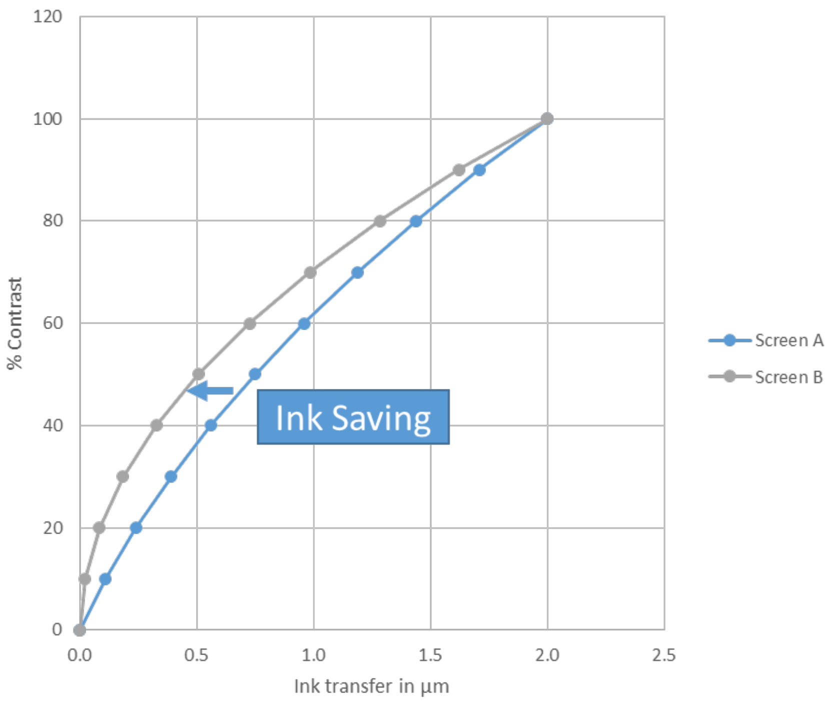
There are clearly many sources of gain, but what if the actual halftone screen itself used was one? We therefore investigate further how different halftone screens impact printed contrast gain.

To do this, we first need to design a test based on the following hypothesis:

> Assume screen "B" is more efficient in generating contrast than screen "A". If so, then we need less ink for screen "B" to print the same contrast compared to a screen "A".

We can confirm or reject the above hypothesis by measuring ink consumption and contrast (using a spectrophotometer) when printing with different screens, e.g., AM and the Hamillroad Bellissima DM screen. For each screen, we print different coverages for which we measure the ink consumption separately. To normalize the ink consumption, we express it as the ink film thickness transferred with unit μm.

The following graph is a simulation of the above hypotheses.



The graph indicates that we need less ink to print the same contrast value for screen "B" compared to screen "A".

Remember, the above graph is a simulation of the hypothesis, but:

Understanding contrast gain might help us evaluate ink consumption when printing halftone images.

3. Test Procedure

A test procedure for measuring ink consumption was designed to evaluate the ink-saving hypothesis when changing the halftone screen type.

The ink consumption in this test was measured on one print station for all tests. On this print station, the ink tub was put on an electronic scale with a resolution of 0.1g.

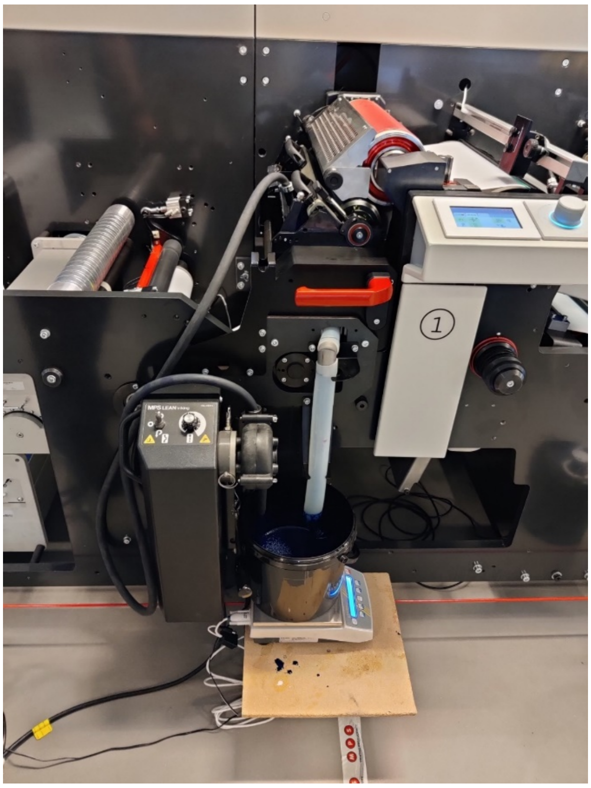
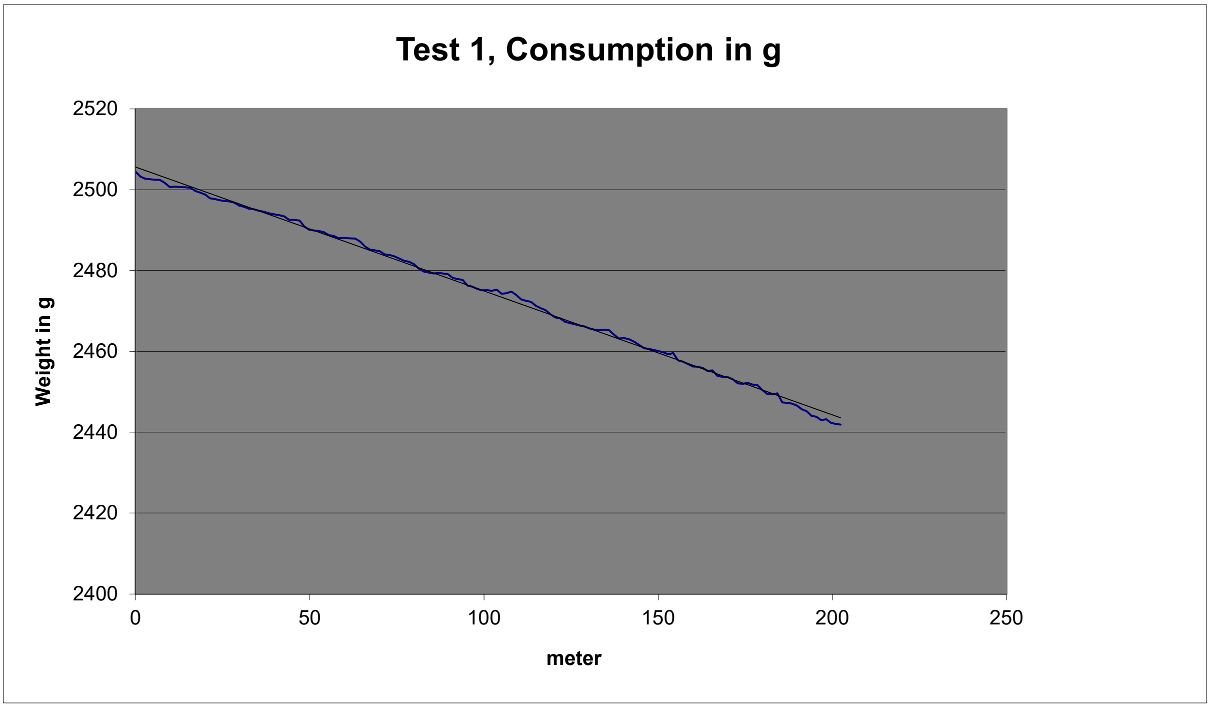


Image of the setup of the print station, scale, and ink tub

The scale value was recorded every time the value of the scale changes. Simultaneously, based on the computer clock speed, it was recorded in a spreadsheet. The machine web speed was recorded as indicated by the printing machine.

It is important to note that we don't use the value indicated by the scale at the start and end of the test for calculating ink consumption but that we use all the data points collected during a test.

The following graph shows the data collected from a typical ink consumption test, including a trend line:



The slope of the trend line can provide a value for the ink transfer. The trend line is calculated from a large number of data points (>200). The slope can be accurately calculated from the collected data using the following linear regression equation:

$$b = \frac{\sum (x - \bar{x}) * (y - \bar{y})}{\sum (x - \bar{x})^2}$$

b = ink consumption in g/m

x = linear speed in m/min

$\bar{x}$ = average speed in m/min

y = weight for given print length in m

$\bar{y}$ = average weight for a given print length interval

The slope value calculated using the linear regression formula divided by the width printed gives a value for ink consumption in g/m^2.

If we now divide the ink consumption value by the ink density of the ink, we get the ink transfer value in µm. That is we divide a value in g/m² with a value in kg/dm³ resulting in the weight values eliminating each other and then only a distance (thickness) value with a unit of µm is left.

Ink transfer is the ink film thickness in µm that is transferred from the screen roll to the surface of the substrate.

You might have already noticed from the print station image that MPS hosted the test and that we used the MPS EF430 as installed in the MPS demo centre at Arnhem in the Netherlands for all tests. The ink system construction on the MPS EF430 allows for very accurate ink transfer measurements with a minimum of disruption caused to the machine ink system.

For all tests, we used the same machine speed: 80 m/min.

The ink used for all tests was UV-based.

The substrate was: 80 g/m² LWC having a prime coating (the smooth, consistent LWC surface allowing for good consistent measurements).

We conducted three days of tests using the following 18 printing plates:

- Full tone
- AM133 LPI (52 l/cm)
    - 85%, 75%, 50%, 25% coverage
- AM175 LPI (69 l/cm)
    - 85%, 75%, 50%, 25%, 10% coverage
- Bellissima Narrow Web eXtended M
    - 90%, 75%, 50%, 25%, 10% coverage
- Bellissima Narrow Web eXtended K
    - 90%, 80%, 50%, 25% coverage
- Bellissima Narrow Web Standard M
    - 90%, 75%, 50%, 25% coverage
- Bellissima Narrow Web eXtended Cyan (BNWXC)
    - 50%
- Bellissima Narrow Web eXtended Yellow (BNWXY)
    - 50%
- Bellissima Narrow Web Standard Cyan (BNWSC)
    - 50%
- Bellissima Narrow Web Standard Yellow (BNWSY)
    - 50%

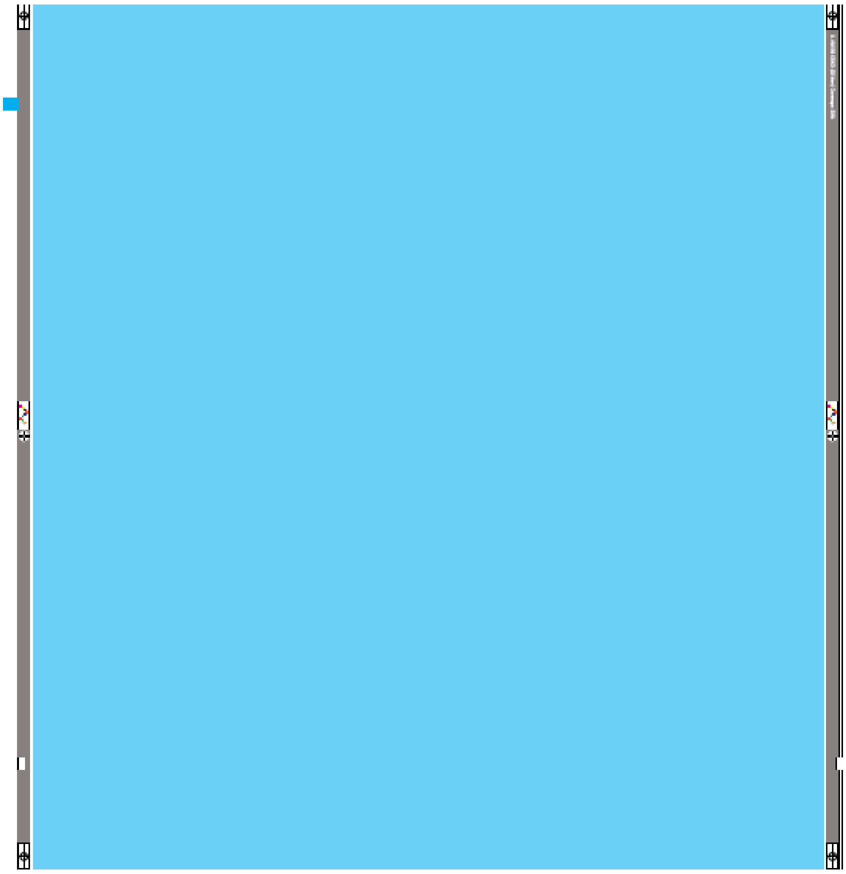
For the tests, we used two screen rolls that had a similar ink film thickness of 3 µm (3 cm^3/m^2) on their surface:

- Conventional Hexagonal (Hex) with 405 l/cm line count
- APEX GTT XS

In total, 46 individual ink transfer tests were conducted on two different test occasions. From each test, print samples were taken for measuring the print contrast.

The design of the printing plates consisted of a large area containing the actual halftone screen tone value being measured, and two side areas with bearer bars and various marks, including those used for correctly mounting the printing plates. These side areas were all solid elements, so acted as full-tone printing areas. The actual printing area of the side areas and the halftone area were measured from the printing plate design file.

The following image shows the design of one printing plate, where the area shown in cyan is the actual area printing the halftone screen tone value being measured. On both sides (left and right), you see the two grey side areas that print as full tone and include the bearer bars and various marks, including those used for mounting the printing plates. The printing plates wrap fully around the sleeve with a consistent small gap of 3 mm for each printing plate.



The ink consumption data measured for a test is the sum of the ink consumption of the halftone area and the ink consumption of the side areas.

The ink consumption of the side areas was assumed to be identical to the ink consumption of the tests using the full-tone printing plates.

The ink consumption of an individual test was corrected by subtracting the ink consumption of the side areas as a fixed value for each test for a given screen roll.

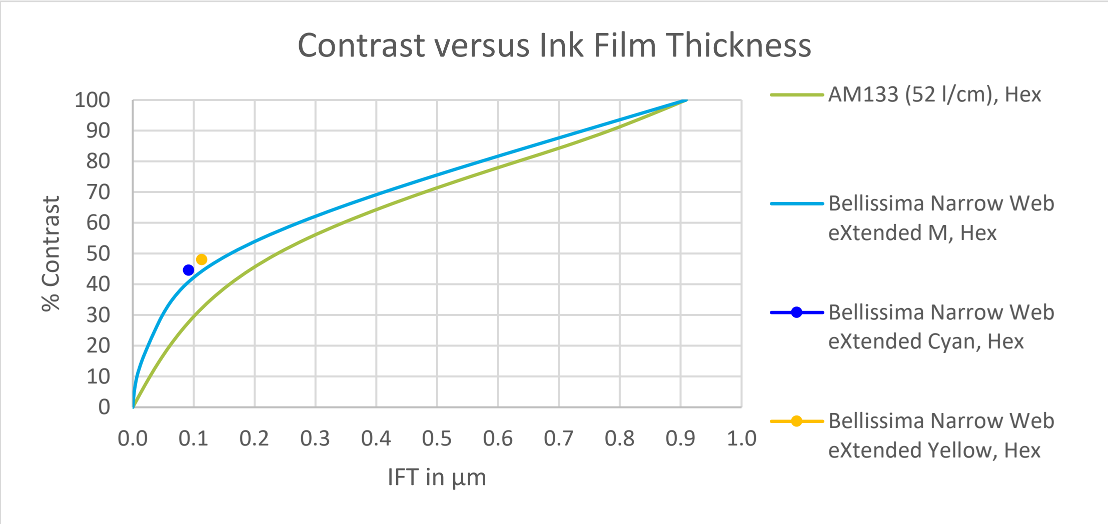
The ink consumption of the full-tone area was slightly different for the two anilox rolls used.

All 46 individual tests were conducted as planned, and there were no problems to report other than a small ink pump failure for one test, resulting in that specific test being repeated.

4. Test Results

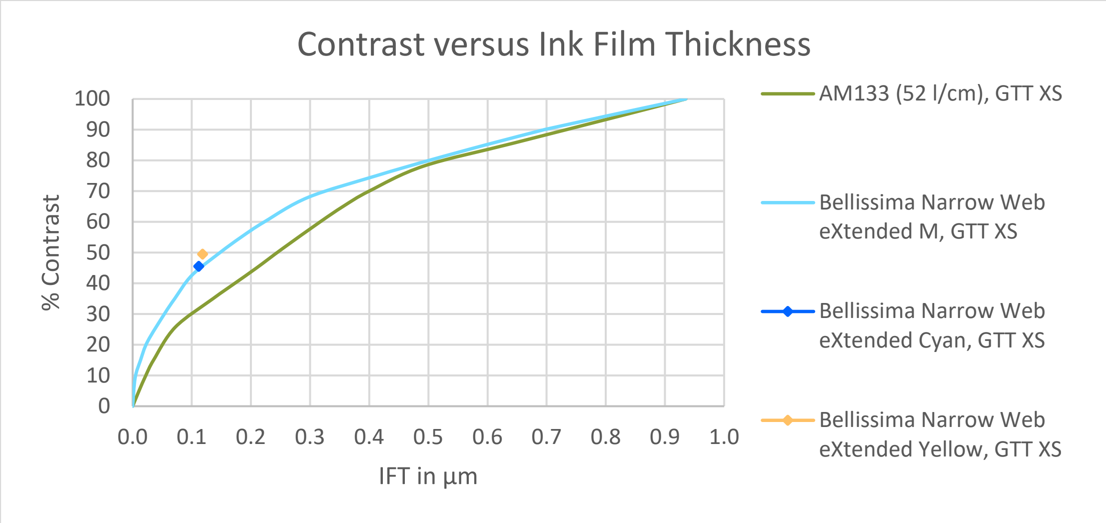
Let's look at the main test results by anilox roll type used, conventional Hex and GTT XS. We will do this by showing a graph, where the X-axis represents the measured and corrected for side area ink transfer (ink consumption) and the Y-axis the measured contrast.

The following graph shows the results for the AM133 LPI (52 l/cm), the Bellissima Narrow Web eXtended M, and the 50% Bellissima Narrow Web eXtended Cyan and Yellow screens, all using the conventional Hex anilox:



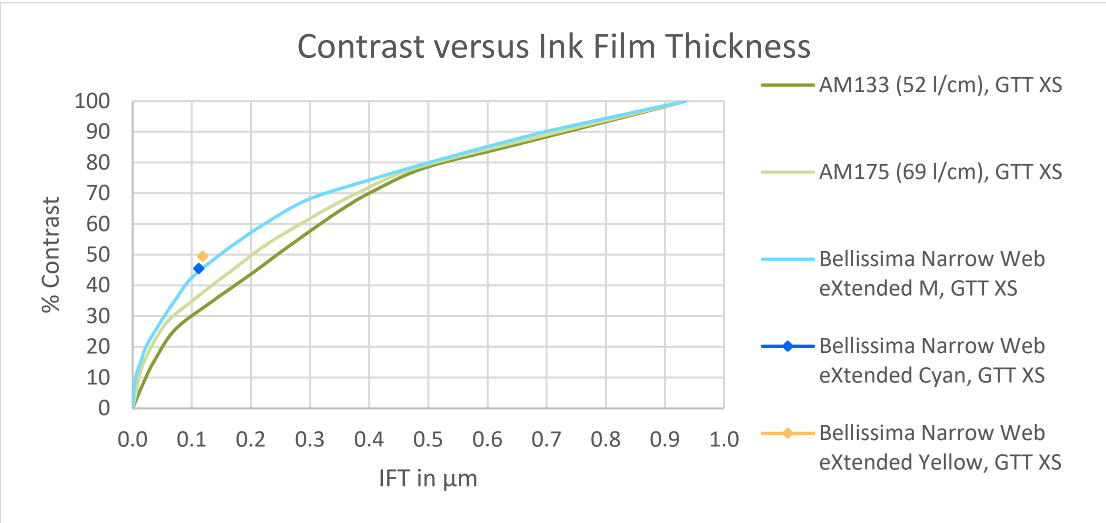
The graph shows that the "Bellissima Narrow Web eXtended M" screen prints a significantly higher contrast using the same amount of ink as the "AM133" screen when using a conventional hexagonal engraved anilox roll.

The following graph shows the test results using the same screens: the AM 133 lpi (52 l/cm), the "Bellissima Narrow Web eXtended M," and the 50% Bellissima Narrow Web eXtended Cyan and Yellow screens, but now using the GTT XS anilox roll:



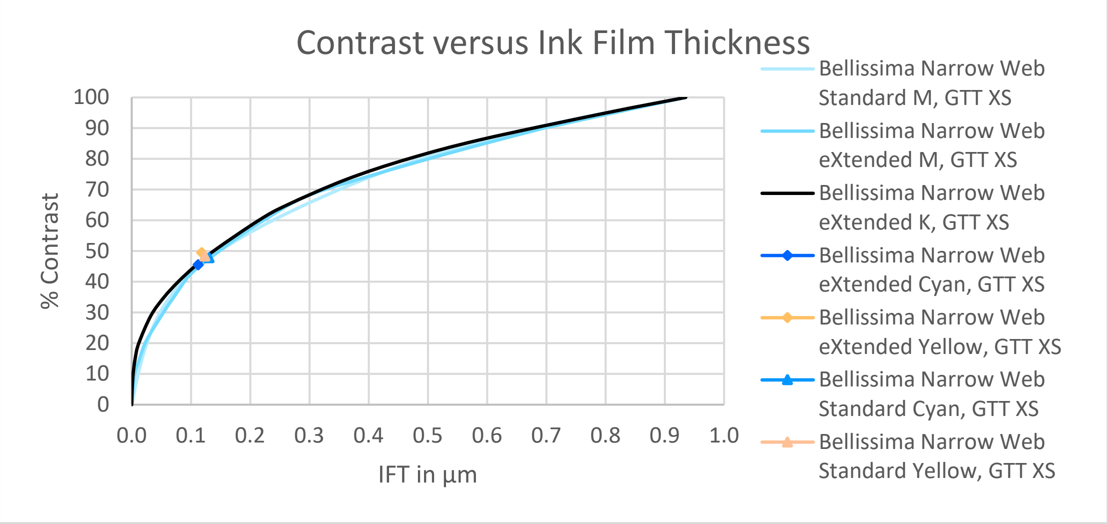
Again, we see that the "Bellissima Narrow Web eXtended M" prints a higher contrast using the same ink film thickness.

We will add to the last graph the AM175 screen.



The AM175 screen sits between the AM133 and the "Bellissima Narrow Web eXtended M". This is logical as the AM175 screen uses a higher line count resulting in smaller dots compared to the AM133. The "Bellissima Narrow Web eXtended M" screen still shows the highest contrast gain using the same amount of ink!

The following graph will compare the different Bellissima screens part of the test: "Bellissima Narrow Web eXtended M", "Narrow Web eXtended K", "Bellissima Narrow Web Standard M" and 50% dots for the Cyan and Yellow screens.



Again, we see differences - but not as big as between Bellissima and a conventional AM screen. This graph shows that the "Narrow Web eXtended K" screen printed with the highest contrast gain when using the same amount of ink.

5. Conclusion

So, what do we learn from this?

The test results show that the hypothesis was correct.

- Contrast gain (Dot Gain) is clearly dependent on the halftone screen that we use to print. The two AM halftone screens show an increase in contrast when using an AM halftone screen with a higher line count. However, there is a limit to the smallest dot that you can print with an AM screen.
  A higher line count AM halftone screen will limit the contrast range you can print. If the smallest dot the printing plate can hold for an AM 133 lpi halftone screen allows you to print a tone range from 2% to 100% full coverage, then that same smallest dot on the printing plate for an AM 175 lpi halftone screen will likely restrict the tone range that you can print to be from 5% to 100%. You don't have this limitation when using the Hamillroad Bellissima screens.

- We can print a higher contrast using the same amount of ink when changing the halftone screen configuration from an AM screen to a Hamillroad Bellissima screen.

- The contrast produced when using the same amount of ink was greatest for the Hamillroad Bellissima screens!

Based on these results, the ink-saving for any given job can also be estimated. However, this ink-saving depends on the ration (distribution) between the different tone areas in an image. A 10% (probably more) ink-saving when printing with U.V. ink and using the Hamillroad Bellissima screen is likely achievable.

The ink savings are nice in terms of ink cost, but ink savings means more!!!

Printing the same contrast using less ink results in the following four benefits:

1. Reduced ink consumption and so reduced costs.
2. Lower energy consumption for drying the ink.
3. Less risk of ink migration thru the substrate. Ink migration thru a substrate might result in contaminating the product that is packed.
4. Less ink in the environment. During the substrate deinking process, which takes place during recycling, less ink needs to be removed and ends up as waste. (Deinking is a problem in the papermaking process).

A 10% reduction in ink consumption and costs might sound good, but that reduction in combination with the other three incidental benefits mentioned above, improves the overall process and sustainability of printing, packing, and recycling.

Hamillroad is planning to conduct further tests for other printing markets, including the use of other ink types such as water-based and solvent inks. There is therefore likely to be more confirmation of potential savings printers can achieve when changing to a different halftone screening system such as Bellissima.

All data used in this article was measured unambiguously.

6. Trademarks

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