DESIDOC Bulletin of Information Technology, Vol. 23, No. 1, January 2003, pp. 43-55

Comparative Study Between Different Digital and Offset Litho Printing Systems

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Abstract

This paper is a comparative study of the output quality and performance parameters of ten most widely used digital colour printing presses and systems, and two offset litho printing systems. This paper uses visual assessment and acceptability tests for comparing the performance of the systems.

1. INTRODUCTION

The ten selected digital colour printing systems print with a speed of more than 1800 (4/0) copies per hour with a resolution of at least 400 dpi. They are compared with two of the most widely used offset litho printing systems, and also with the ISO 12647-2 standard.

Schläpfer[1] distinguished between the digital printing systems on the one hand, and the digital copiers and office printers on the other, by two main criteria, which both should be met:

(a) The productivity of the system should be at least 1500 (4/0) copies per hour.

(b) The resolution should be at least 600 dpi, or if less, the system should have the capability of reproducing continuous tones and using special screening techniques.

The twelve selected systems are:

- The Quickmaster DI 46-4 from Heidelberg, and the Adast CDI from Omni Adast, as examples of the digitally imaging (on press) waterless offset printing systems.
- The E-Print 1000 TurboStream from Indigo, an example of the liquid toner electrophotographic computer to print systems.
- The DCP/32D from Xeikon, the Chromapress 32i from Agfa-Gevaert, the InfoColor 70 from IBM, and the DocuColor 70 from Xerox, as examples of the 600 dpi dry toner electrophotographic computer to print systems.
- The DocuColor 40 from Xerox, the CLC 1000 from Canon, the Colour System 200 from Oce, as examples of the 400 dpi dry toner electrophotographic computer to print systems.
- The GTO 52 and the SM 52 from Heidelberg, as examples of the offset litho printing systems, without and with alcohol dampening systems.

2. PRACTICAL TESTS

In order to compare these twelve systems, Heidelberg UK prepared a single test file. The file was A3 in size and contained several test images and control strips with solid and halftone single and overprint colour patches.

The test file was sent to all the manufacturers, asking them to produce a minimum of 20 copies on 150-gsm mat coated paper using the default adjustments they have for the best quality output.

The measurements on the following nine parameters were done on ten random samples from each system:

- Density
- Dot gain
- Characteristic curves
- Contrast
- Trapping
- Hue error
- Grayness
- Spectral reflectance curves
- Colour Gamuts.

These nine parameters will give a reasonable comparison between the systems, since they represent a printing system's main output characteristics.

The measurements were done using a Gretag D196 densitometer, (with the Status T Standard and polarization filters), for all the parameters except the colour gamuts and reflective curves, for which a Gretag Spectrolino spectrophotometer was used, with the illuminant D65, observer angle 2, DIN standards.

The measurements were done using a black background, as stated in the ISO standards, and using the papers' white as the reference white, in order to eliminate any effects caused by the used papers' colouring and surface characteristics on the evaluation of the printed ink (or toner) film thickness.[2]

2.1 Results

The results of the measurements are given below. The average values of the measured parameters are presented as comparative charts in order to make the discussions of the results easier.

(a) Density

Reflection density of a print is the measurement of the amount of ink (or toner) laid down on paper (or substrate) by a press. The solid densities of the 4-process colour patches of the 12 systems were measured (Figure 1).

(b) Dot Gain

Dot gain is the difference in the dot area measurements from the film or digital file to the printed image. The dot gain of the 4-process colours (Cyan, Magenta, Yellow, and blacK) (CMYK) of the 12 systems were measured, at the solid, 80%, and 40% halftone patches (Figures 2 and 3) using the Murray-Davis equation.

(c) Characteristic Curves

The characteristic curve is the relationship between the dot percentages on the film (or digital file) and those on the final print. The dot areas of the 4-process colours (CMYK) of the 12 systems were measured (Figure 4).

(d) Contrast

The print contrast is the measurement (on a scale of 0-100%) of the ability of the printing

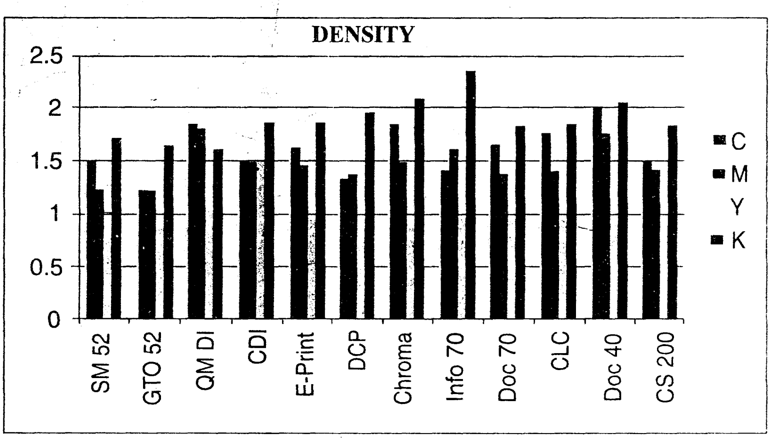

Figure 1. Density

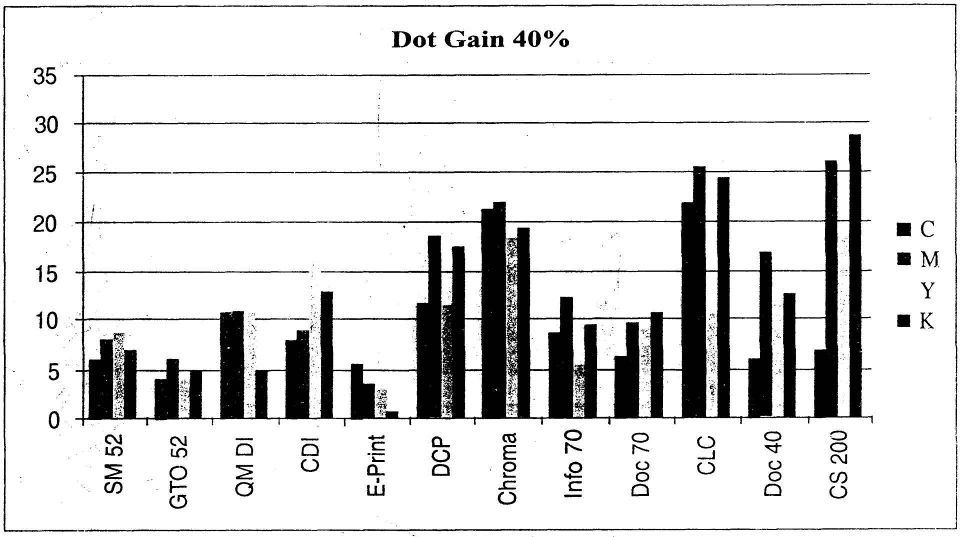

Figure 2. Dot Gain 40%

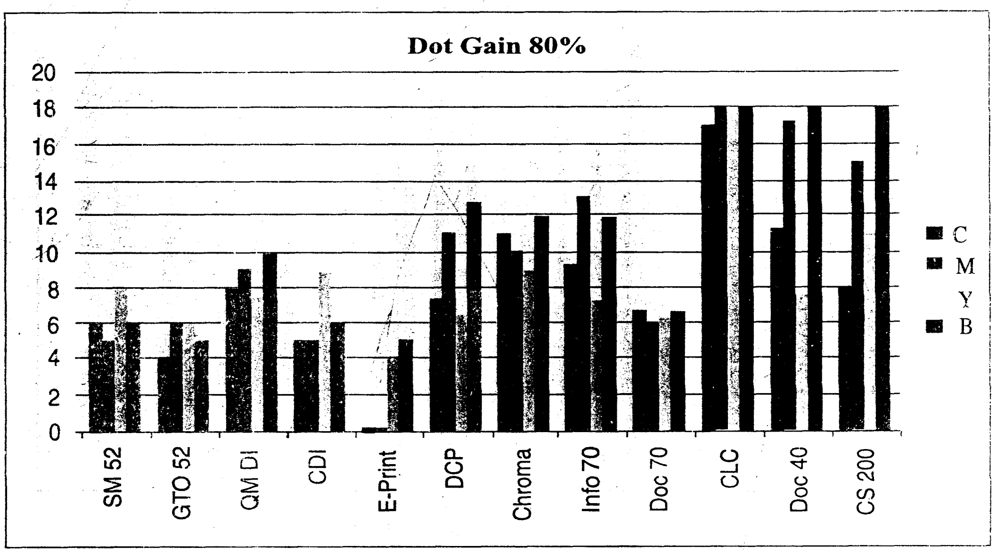

Figure 3. Dot Gain 80%

process to hold shadow detail. It compares the density of a solid patch with that of a halftone patch, which is usually a 75% screen. The contrast of the 4-process colours (CMYK) of the 12 systems was measured (Figure 5).

(e) Trapping

Trapping is the measurement (on a scale of 0-100%) of the ink (or toner) adhesion on a previously printed ink or toner film.[3] The trapping of the three-overprint colour patches, Blue, Green and Red, of the 12 systems were measured (Figure 6).

(f) Hue Error

The Hue error value indicates the variation and deviation (on a scale of 0-100%) of the measured ink (or toner) colour from the theoretically perfect one. Figure 7 shows the hue error of the three process colours (CMY) of the 12 systems.

(g) Grayness

The Grayness value indicates the grayness (gray component) and darkness variation (on a scale of 0-100%), between the measured ink (or toner) and the ideal ones. The grayness of the three process colours

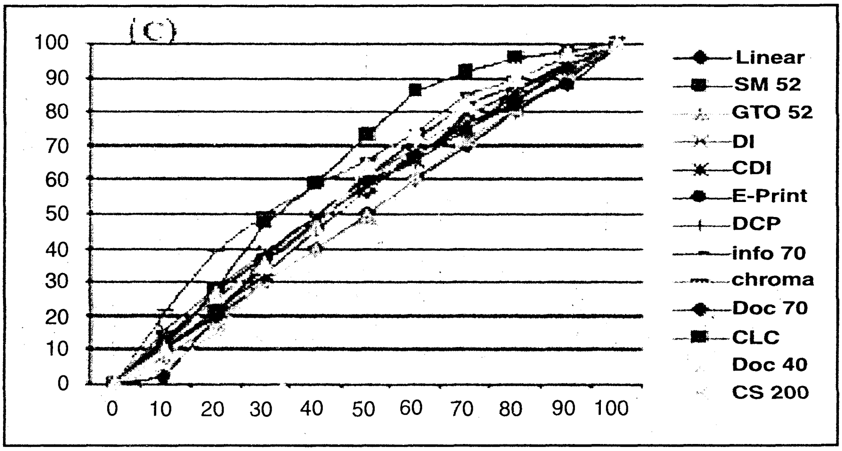

Figure 4. Characteristic Curves

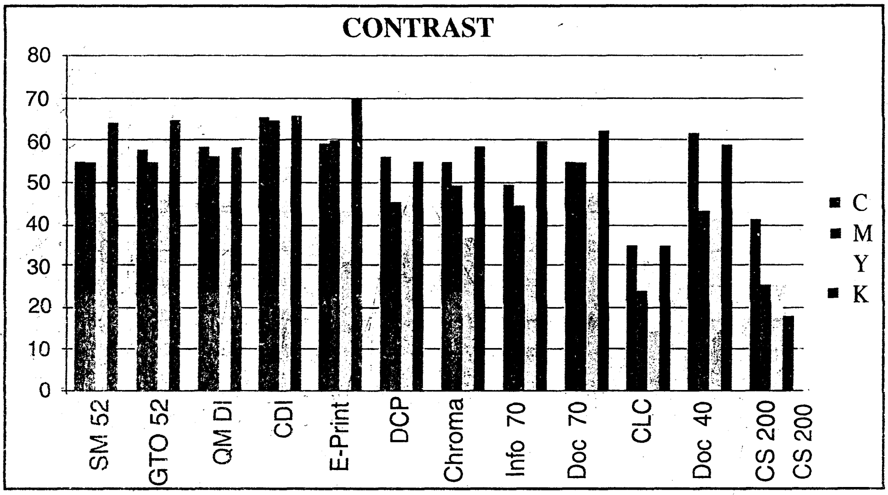

Figure 5. Contrast

(CMY) of the 12 systems is shown in Figure 8.

(h) Spectral Reflectance Curves

The Spectral reflectance curve illustrates the reflectance of the light from a surface, such as paper (or a print), wavelength-by-wavelength throughout the visible spectrum as a means of determining the colour of that surface.[4] The spectral reflectance curves of the four-process colours (CMYK) of the 12 systems were measured (Figure 9).

(i) Colour Gamuts

Colour gamut is the total range of colours that can be reproduced with a given set of inks (or other colorants) on a given paper stock and a given printing press (or other colour output) configuration.[4]

The data here was presented in the CIE L*a*b* space. The L*a*b* values of the six basic colour patches (CMYRGB) of the 12 systems were measured (Figure 10).

2.2 Discussion of Results

It may be argued that comparing the results of the digital systems with those of

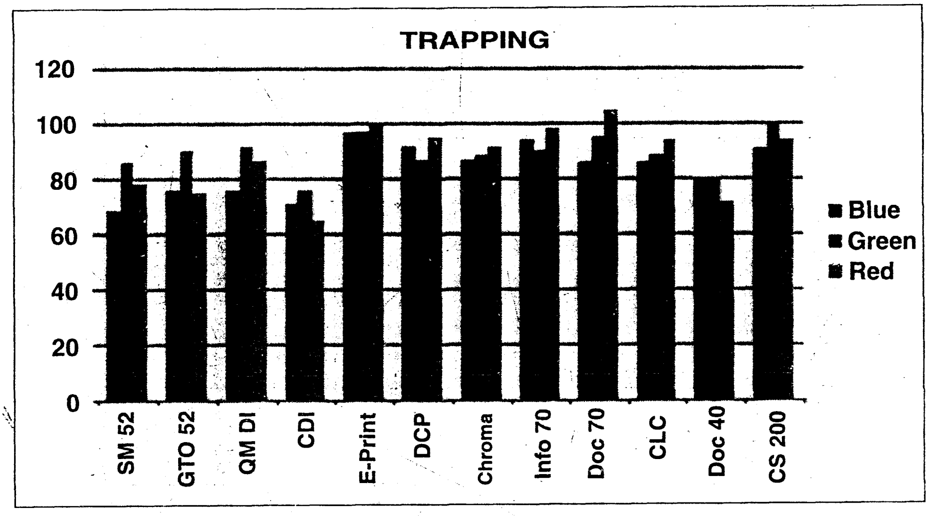

Figure 6. Trapping

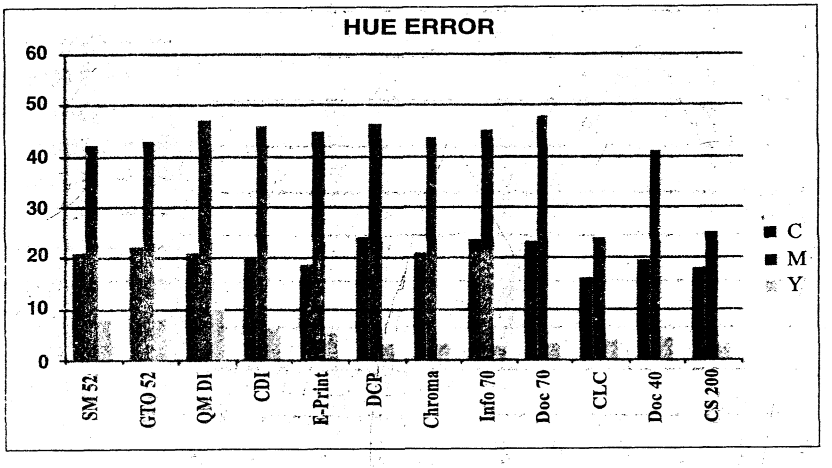

Figure 7. Hue Error

offset litho Standards will not be appropriate since the systems and their consumables are different. However still we'll be referring in some cases to the ISO 12647-2 Standard as a comparison guide, since it is the most widely accepted international standard, and the most related one to the tests we've done using CMYK files without any colour transformations, which is the usual, every day production method in general offset litho printing.

(a) Density

The density measurements show that:

- All the (C) colour density readings, with the exception of those of InfoColor 70, DCP 32/D, and GTO, were higher than the one recommended by the ISO (1.45).

The nearest to the standard was SM 52 (1.47).

- As for the (M) colour, the density readings were closer to the ISO Standard, where the CLC density reading was exactly as the recommended one (1.4).

The density readings of the (Y) colour were overall the best compared to the ISO Standard, where DI had exactly the recommended value (1). All the results, except those of DI and Adast were less than the standard.

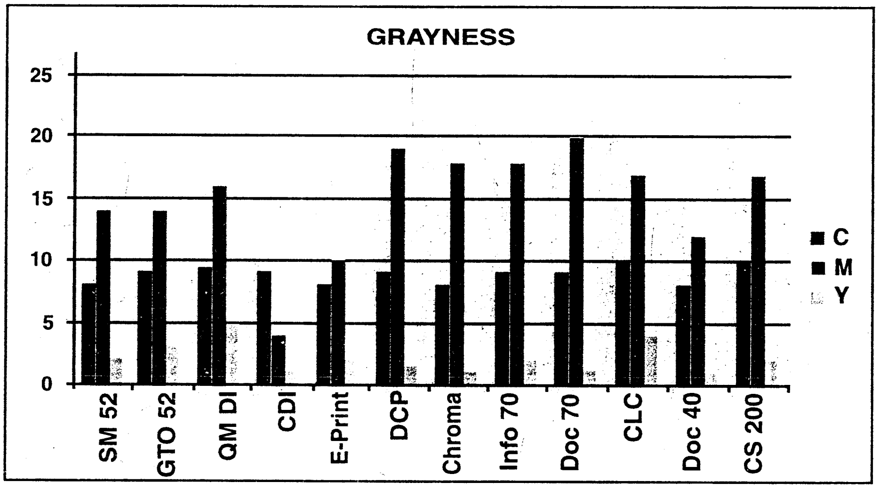

Figure 8. Grayness

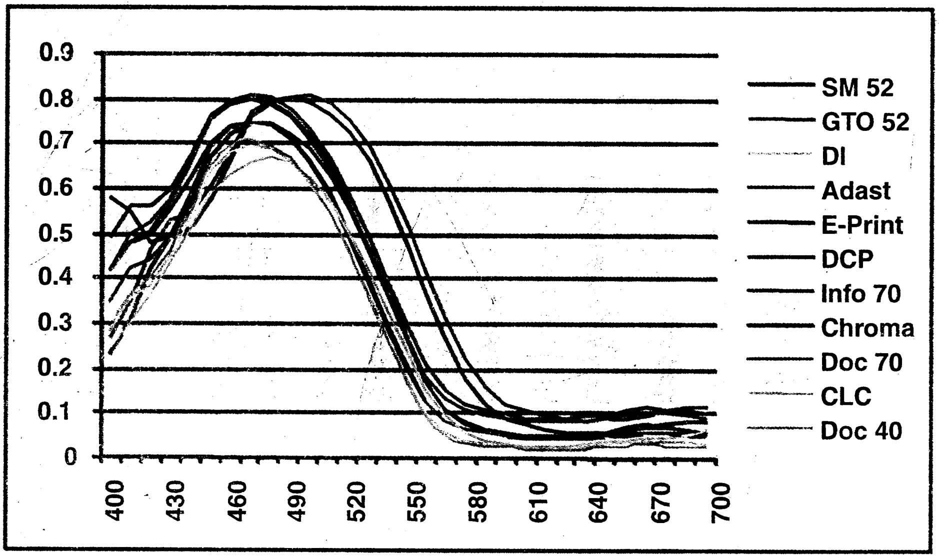

Figure 9. Spectral Reference Curves

- As for the (K) colour, all the density readings except those of the SM 52, GTO and DI, were higher than the standard (1.75). The closest to the standard was SM 52 (1.72).

The overall balance between the densities of four colours for each system was different, in most cases, from the standard's recommended one. The density values can be altered through the software of the front ends and RIPs.

(b) Dot Gain

The (C) colour's dot gain values at the 40% halftone patch, except that of DCP, were not within the tolerance range (12% to 20%) recommended by the ISO standard. The dot gains of only CLC (22%) and Chromapress (21%) were higher than the recommended standard. At the 80% patch, only InfoColor, Chromapress and DocuColor 40 were within the range (9% to 15%).

For the (M) colour, at the 40% patch, DCP, InfoColor and DocuColor 40 were within the range with DocuColor 40 being the closest to the target.

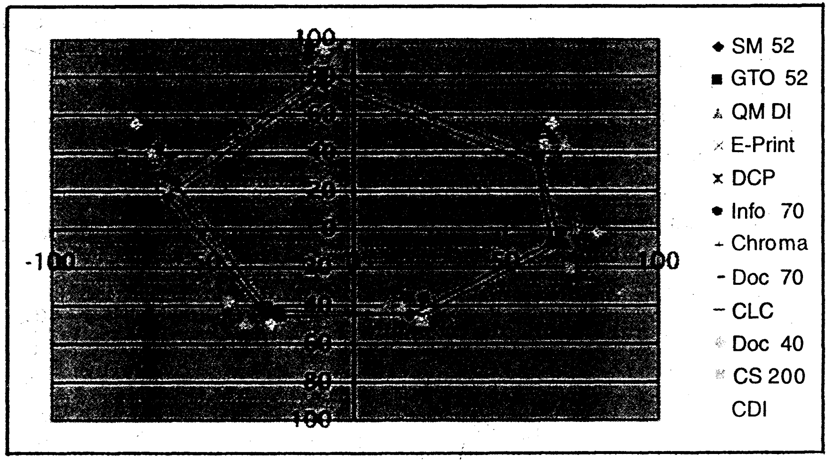

Figure 10. Colour Gamuts

At the 80% patch, DI, DCP, InfoColor, Chromapress and Oce´ were within the range, DCP and InfoColor being the closest to the target.

As for the (Y) colour, at the 40% patch, DCP, Chromapress, DocuColor 40, Adast and Oce´ were within the range with Adast being the closest to the target. All the rest were lower than the range.

At the 80% patch, only Chromapress, Oce´ and Adast were within the range.

For the (K) colour, at the 40% patch, DCP, Chromapress and DocuColor 40 and Adast were within the range, with DCP being the closest to the target. E-Print again was the lowest (1%).

At the 80% patch, DI, InfoColor, DCP and Chromapress were within the range. Chromapress had exactly the target value.

The relation between the 40% and 80% patches' dot gain values for each system was different, some had both values equal, and others had the first or second value higher. Dot gain values can be altered through the RIP of the systems.

(c) Characteristic Curves

For the (C) colour, Chromapress had the highest values at the first half of the curve while CLC had the highest at the second half of the curve reaching its peak at 60%.

The rest of the systems were nearly the same, except that E-Print had very low values at the very beginning of the curve and low values at the end of it indicating that some of the dots were not printed on the paper at this area.

GTO was the closest to the ideal linear curve.

For the (M) colour, Chromapress had the highest values at the first quarter of the curve, while Oce´ and CLC had the highest at the rest of the curve, reaching its peak between 60% and 70%.

E-Print had the lowest values, which were again very low at the very beginning of the curve.

As for the (Y) colour, Chromapress had the highest values at the first 2/3 of the curve, while CLC had the highest at the last 1/3 of it, reaching its peak at 70%.

CLC had the lowest values at the very beginning of the curve, which were even lower than the linear 45° curve, indicating that some of the dots were not printed on the paper at this area.

For the (K) colour, Chromapress had the highest values at the first quarter of the curve, while Oce´ had the highest at the rest 3/4 of it, reaching its peak between 60% and 80%.

DocuColor 40 had the lowest values at the very beginning of the curve, which were even lower than the linear curve, indicating again that some of the dots were not printed on the paper at this area.

(d) Contrast

From the contrast, it was clear that all the contrast values were higher than the maximum ones of SWOP standard's recommendations, except the CLC and Oce´ ones, where CLC had lower (M) and (Y) contrasts, and the Oce´ had lower (M) and (K) contrasts.

The lower contrast of CLC and Oce´ is correlated to its high dot gain values.

Here, we are referring to the SWOP standards instead of the ISO ones, where contrast values are not mentioned in the later, since it is in a way representing the same information as the dot gain.

(K) colour contrast was overall the highest, with ten of the twelve systems over (50%), (C) was second with nine systems over (50%), (M) third with six systems over (50%), and (Y) the lowest with only one system over (50%).

Changing the dot gain values, through the RIPs and software used, can change contrast values.

(e) Trapping

The range for the Blue colour was from 68% for SM 52, to 97% for E-Print.

For the Green colour, the range was from 76% for Adast, to 99% for Oce´.

As for the Red colour, the range was from 65% for Adast, to 100% for E-Print and DocuColor 70.

Overall, the Red colour's trapping was the best, with seven out of twelve systems having over 90% trap. All of the electrophotographic systems' Blue and most of Red colours' traps were higher than the offset litho, DI and Adast systems, reflecting the greater adhesion of dry toner on previously printed layers, as compared to the lower wet-on-wet adhesion of ink films.[3]

Adast had the overall lowest values, while E-Print had the overall highest.

(f) Hue Error

Magenta colours had the highest error in all the systems with all of them (except CLC and Oce´) being over 40%.

Cyan colours were second, the range being 16% for CLC to 24% for both DCP and InfoColor 70.

Yellow colours were the best, with all the dry toner based systems below 5%, the E-Print and Adast were 6%, the GTO and SM 52 were 8%, and the DI 10%.

(g) Grayness

Magenta colours had again the higher values, ranging from 4% for the Adast to 20% for DocuColor 70.

Cyan colours were second with less grayness, ranging from 8% to 10%.

Yellow colours were the best, with all the systems less than 5%, the Chromapress, DocuColor 40 and 70, Adast, DCP being only 1%.

(h) Spectral Reflectance Curves

In the (K) colour curves, there were almost no differences between the twelve systems. Only the Chromapress had a higher reflectance at the 400 - 420 nm area.

In the (C) colour curves, there were little differences between the systems.

Again the Chromapress had a slight (a gradual 10%) increase in its reflectance between the 400 - 420 nm area.

The SM 52 and GTO had a higher reflectance in the range from 500 - 590 nm.

As for the (M) colour curves, there were also little differences between the systems within the 630 - 700 nm area.

In the (Y) colour curves, there were little differences between the systems within the 550 - 700 nm area, where the DI was the lowest. Also within the 400 - 480 nm area, the systems were still close to each other.

The increasing reflection of the Chromapress within the 400 - 420 nm area in all colours, was because of a fluorescence effect, which was inspected under UV light.

(i) Colour Gamuts

- The Lightness (L*) values were all very close to the ISO Standard recommendations.

The lightness values of the Red colour were overall the best with only a maximum difference of 5 from the ISO Standard. The largest difference was that of the Green colour, with a maximum difference of 11.

- The Chroma (C*) values of the (C) colour were overall the best with only a maximum difference of 5.5 from the ISO Standard. The largest difference was again that of the Green colour with a maximum difference of 19.
- The Hue angles (h*) of the (Y) colour were overall the best with only a maximum of 3° difference from the ISO Standard. The largest difference was again that of the Green colour, with a maximum difference of 22°.

From the colour gamuts' comparison chart, (Figure 10), most of the above results were clear. It can also be seen that:

- CLC had the largest gamut in the (Blue), (M), (G) to (C) and (G) to (Y) areas.
- DocuColor 40 had the largest gamut in the (Y) to (R), and (R) to (M) areas.
- DI had the smallest gamut in the (Y) to (G) area.

All of the digital (G), (Y) and (R) colours, most of the (C) and (M) colours, some of the (B) colours were out of the offset litho colour gamuts.

Finally the ΔE* values were measured which are the colour deviations and differences between each of the six primary and secondary colours (CMYRGB) of the twelve systems and those of the ISO 12647-2 standard.

From the 72 colours measured, only 6 had an acceptable below 5 ΔE* values.

A majority of 29 colours had values between 5 -10 ΔE* which is more than the acceptable value. All the rest had ΔE* values over 10, which is much more than the accepted value.

2.3 Summary of Results

From the previous discussions we can conclude the following:

(a) Density

Most of the (K), (C) and (M) densities were higher than those of the ISO standard while most of the (Y) ones were lower.

(b) Dot Gain

Most of the dot gain values were outside the ISO tolerance range.

(c) Characteristic Curves

Some of the systems, like the E-Print (in C, M and Y colours), CLC (in M and Y colours), had some of the dots missing at their lower (0 - 20%) halftone patches, and the E-Print had the same at its higher (C) and (M) (90% - 100%) halftone patches.

(d) Contrast

All contrast values were higher than those recommended by SWOP, except those of the CLC's (M) and (Y) colours.

(e) Trapping

All the (B) and most of the (R) colours' trapping values of the digital systems were higher than the offset litho ones.

Overall the (R) colour trap was the best.

(f) Hue Error and Grayness

(M) colours had the highest hue error and grayness values in all systems while (Y) colours were the lowest.

(g) Spectral Reflectance Curves

(K) and (C) spectral curves of all systems were similar to each other with an overall maximum reflection difference of 10% .

The fluorescence effect in the Chromapress four colours' reflectance curves was significant.

(h) Colour Gamuts

(R) colours were the closest to the ISO standard in lightness, while (C) colours were the closest in chroma, and (Y) colours in hue angles. (G) colours were the worst in all three parameters.

The colour gamuts of these digital systems, which were mostly larger than those of the ISO standard's, can be mapped and matched to those of the later, by using the latest colour management software.

Since the above mentioned parameters are not the only measures in comparing the output quality, some preliminary visual assessments were also made on the test prints. The results are as follow:

- Contouring was acceptable in all the systems except in CLC and DocuColor 40.
- Text production for the Helvetica light and bold was produced perfectly even with the 3-point letters. The same was true for the Helvetica bold reversed letters. With the Helvetica light reversed letters, the 3-point letters were partially filled-in with all the systems with E-Print being nearly completely filled-in .
- The theoretical width of the smallest depictable lines were: 8 microns for both the SM 52 and the GTO, 20 for both the DI and the Adast, 31 for E-Print, 42 for DCP, Chromapress, InfoColor and DocuColor 70, 63 for DocuColor 40, and 64 for both the CLC and the Oce´.

3. VISUAL ASSESSMENTS

Visual assessment and acceptability tests were done on the previously compared printed samples by the final users. Since the buyer of a poster, for example, will not measure the printing parameters. What he or she will do will be picking up the most pleasing and appealing prints from his or her point of view.

The human eye will, at the end of the day, be the final examiner, tester and decider of the best pleasing printing results of these different systems.

3.1 Tests' Design

The prints used in the previous comparison tests were shown to a panel of twenty observers who have different printing and colour backgrounds and who have been working in the British and Egyptian printing industries.

First they were asked to rank the prints from the best (most pleasing and appealing) to the worst. Then, in order to determine the visual acceptability of each system, they were asked to specify if each of them is accepted or not, as a match to an Agfa PressMatch Dry proof of the same file, prepared from the colour separated films. Both the films and the proof were very prepared by Agfa UK. All the assessments were done under D50 standard illumination.

3.2 Results

The ranking and evaluation of the twenty observers for each of the twelve systems are shown in Figure 11.

Where a system was first in the ranking, a score of 12 was given to it, where it was second a score of 11 was given, and so on till the twelfth place in the ranking, where only a score of 1 was given.

The results of the acceptability assessments are shown in Figure 12, where a system was accepted by an observer, a score of 1 was given and where it was not accepted, a score of 0 was given. These

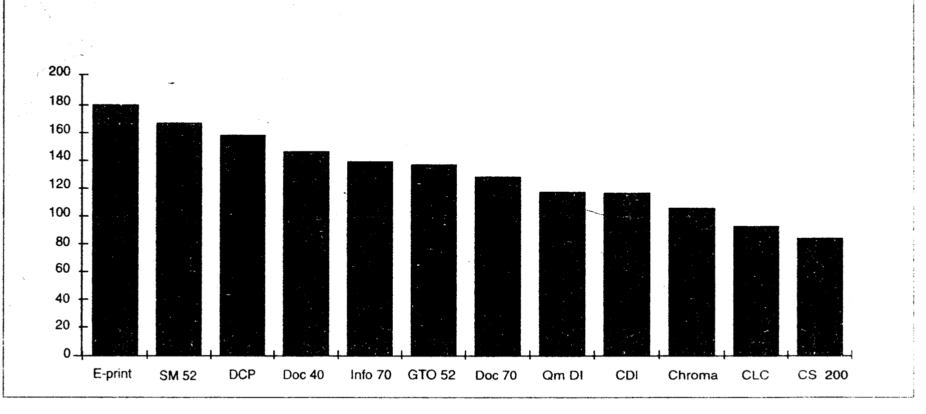

Figure 11. Visual ranking and evaluation

results were multiplied by 10, in order to match (to a certain extent), the visual assessment results.

Figure 12 shows the relation between both the visual ranking and acceptability results.

3.3 Discussion of Results

From the visual assessments of the twenty observers, it can be seen that Indigo had the best (highest) overall pleasing results followed by the SM 52 while the least overall pleasing results was that of the Oce´. Second lowest was the CLC system.

- As for the acceptability of the prints compared with the Agfa proof, again both Indigo and SM 52 came out as the best match, followed by Xeikon, and the lowest match was that of the Chromapress.

- The three best visually assessed systems (Indigo, SM 52 and Xeikon), were also the best in matching the proof, with the same sequence.

The lowest visually assessed ones (Oce´, CLC and Chromapress) were the worst in matching the proof, but with a slight change in their sequence.

The middle range systems, were different in their both rankings, which means that even though some were pleasing to the eye, they didn't match the proof, and vice versa.

- As for the average actual ΔE^* values, comparing the systems with the proof, (Figure 13), surprisingly enough, the Oce´ which came the lowest in the visual

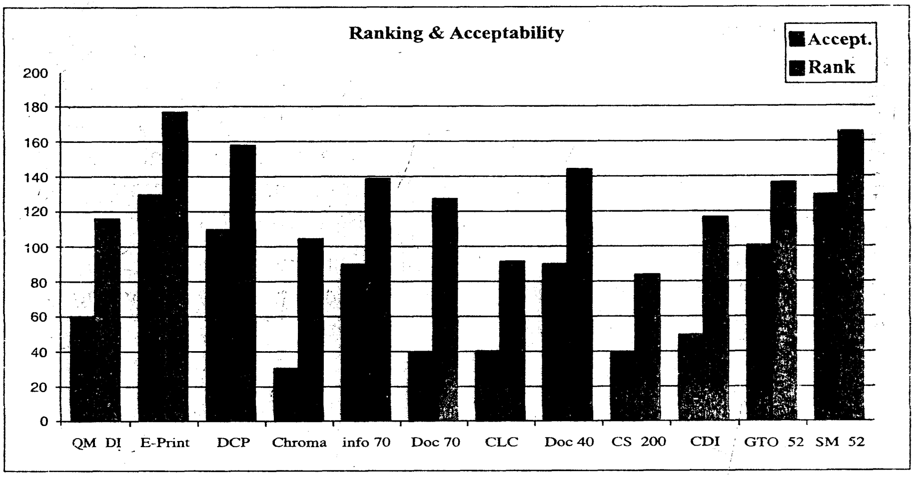

Figure 12. Relation between visual ranking and acceptability

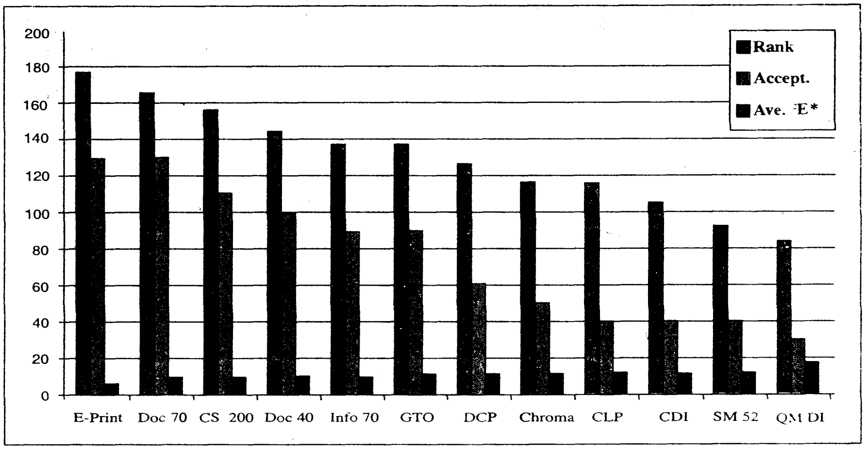

Figure 13. Comparison of the systems with the proof for the average actual ΔE^* values

assessment, and acceptability, came out as the 3rd best in the ranking.

Indigo was again the best, followed by Doc 70, while the DI was the lowest followed by the SM 52, although the later was the second best in both the ranking and acceptability assessments.

Figure 13 showed that colour is not the only factor or criteria in deciding which print or system is the best, there are many other factors, such as resolution, gloss and sharpness, which play a significant role in this decision.

The offset litho inks were less closer in matching the proof eventhough the proof was prepared from the films made to be used in offset litho printing. Gloss played a significant part in some of the observers' decisions while others were looking mainly at grey balance, colour casts, tone reproduction and real natural colours.

7. CONCLUSION

Despite the fact that these systems differed from one another in the quality of their output, each of them can be the best in satisfying certain needs at certain market sectors. It is also expected that during the next few years, they will become better and better, producing higher quality prints.

It is important to note that these results may not represent the best possible output quality of the systems compared. These are the results from the tests with a combination of substrates, consumables, printing conditions, measuring equipment and conditions. The use of different combinations of substrates, consumables, RIPs, front ends, colour management and software adjustments may affect the results.

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