Colour Gamut Improvement When Using FM-Screening

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Keywords: Offset, Screening, Colour gamut, TAGA Proceedings

Abstract: Colours printed with non-periodic (FM) screening produce a higher colour gamut as compared to dot centered printing with periodic screening. It was proved by colour measurement that FM-prints, particularly in the midtone range, exhibit a higher lightness at the same chroma. The reason for this effect is now assumed to be a more homogeneous distribution of ink on paper. Still images taken of the nip of an inked running roller system using ultra-high speed flash video recordings led to the conclusion that ink distribution is influenced by splitting in the roller nip and the formation of small accumulations of ink.

The characteristics of image reproduction by offset printing after non periodic (FM) screening have been repeatedly reported (Maetz, D. J., 1992), (Pfeiffer, H., 1993), (Wolf, K, 1994). The main advantages are higher image resolution offering better reproduction of image details and avoidance of moiré. The latter is an important aspect for the reproduction of images with regular structures such as textile patterns. Little is known about the influence of the FM-screening technique on the printed colour and/or the colour gamut (Silver, J., L., Sanat Hazra, Anson H., 1981).

Comparing prints of the same object, the one produced using conventional dot centered (AM) screening and the other using non periodic (FM) screening one can clearly observe differences in colour: the non periodic screened colours appear more colourful, purer and/or more brilliant (Brune, M., Paul, A., 1994) (Schmid, E., 1994). For systematic analysis of this phenomenon colour measurement was performed on tone scales produced by offset printing using both screening techniques.

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It turned out that, compared to the conventionally screened prints, areas at equal tone value showed a higher chroma and/or lightness when FM-screened, especially in the midtone range. This effect is shown best when lightness L* is plotted as a function of chroma C* (Figure 1): the curve representing the FM-screened cyan areas shows higher values of L* compared to those of AM-screened areas. However, it is not just FM-screening that affects colour in this way. When using high dot frequency in conventional dot centered (AM) screening, e. g 240/cm (approx. 600/inch), colour is affected in the same way (Figure 2). Therefore, it is the fact that the printed dots are smaller that causes higher lightness and chroma of the colours and therefore an improvement in colour gamut.

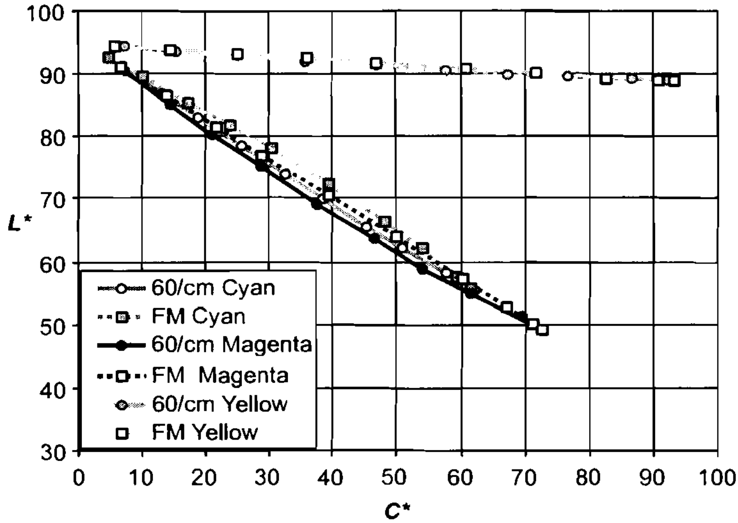

Figure 1: Offset: Lightness L* and chroma C* of tone scales printed after AM- and FM-screening

In order to evaluate the extent to which the gamut is increased, the number of distinguishable colours reproduced in the offset printing process was calculated. For this purpose the assumption was made that for each colour to be distinguishable from its neighboring colour it must be separated by a colour difference of $\Delta E^*_{ab} = 1$. Based on this assumption, the colour space reproduced by a printing process can be filled up by tetrahedrons with an edge length of $\Delta E^*_{ab} = 1$. Calculated in this way, using a gloss coated paper, 497,000 colours can be reproduced in conventional offset printing. Using FM-screening (Agfa Cristal screening) the number of colours rises to 573,000 which means an increase of 15.4 %.

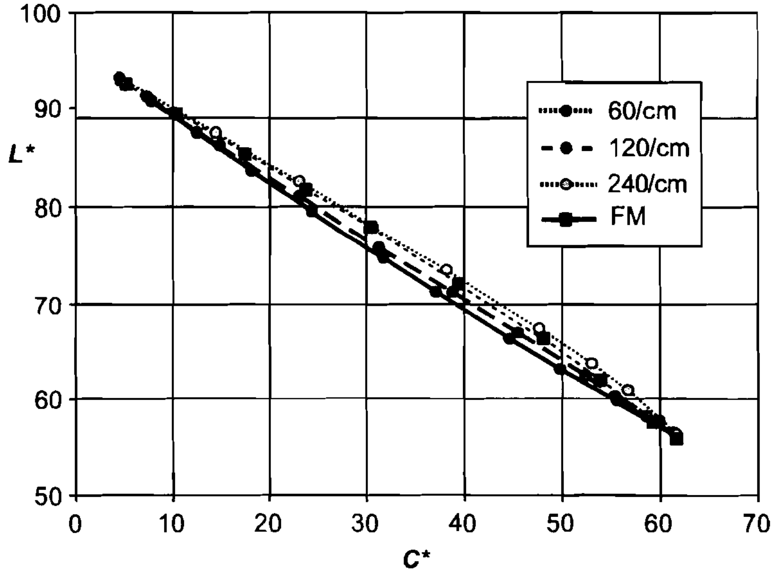

Figure 2: Offset: Lightness L* and chroma C* of tone scales printed after AM-screening at different frequency compared to FM-screening

What is the reason for the observed effect?
At the first glance one might ascribe it to a higher tonal value increase being associated with the finer screen ruling and/or the smaller dots. To find out whether this is true or not, prints were produced on two foils with different opacity the latter being supposed to have an influence on light trapping and therefore on tonal value increase. Figure 3 shows that, for a given screening process, the individual values measured after printing on the two different foils all lie along the same curve, with, as expected, a displacement corresponding to the shift in tonal value, and the curves plotted for AM-screened prints on foils with different opacity are almost identical. On the other hand, using the FM-screening process, higher lightness is measured for both foil types. Therefore, a different tonal value increase during printing when using the different screening processes can't be held to be responsible for the observed colour gamut improvement.

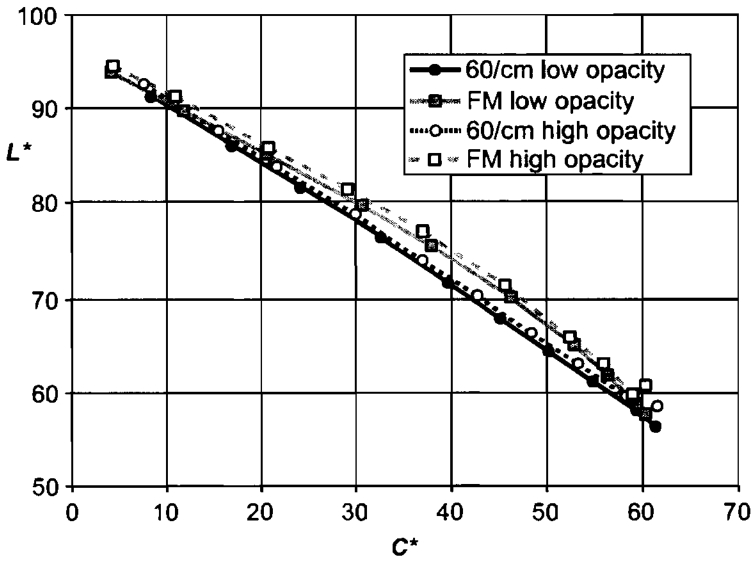

Figure 3: Chroma C* and lightness L* of AM- and FM screened prints on foils of different opacity

Reasons other than tone value increase are supposed to cause the observed colour gamut improvement. One aspect considered was the ink layer distribution on printed dots. Normally increasing the ink layer thickness is only thought to intensify the colour i. e. to increase the chroma C*. On the other hand, it is well known that a higher ink layer thickness also causes a printed colour to darken, i. e. to be reduced in lightness L*. This is particularly true for the "dark" colours such as blue and red.

A printed dot in the midtone range conventionally screened with a ruling of 60/cm (150/inch) has a diameter of approx. 130 µm. After the splitting of the ink film in the roller nip the ink is not transferred to a dot on the substrate in a homogeneous layer. Apart from the well known fact that the edge of an offset printed dot is disrupted to a varying extent depending on the surface properties of the paper, ink is accumulated in the center of the dot, making it darker than the edge (Figure 4 a).

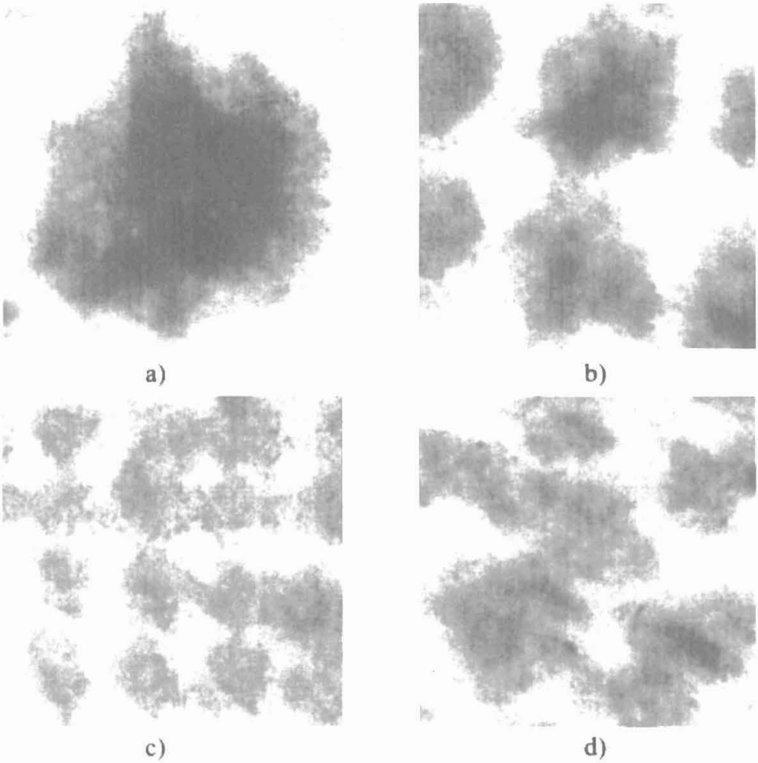

Figure 4: Printed dots (Cyan) after screening with different rulings
and FM-screening
a) 60/cm, b) 120/cm, c) 240/cm, d) FM

Printing small dots with a diameter of only 30 µm or less, as is normal with FM-screening, reduces the build up of ink in the center of the dots and therefore the darkening effect (Figure 4 d).

Consequently, a tone area printed with small dots, i. e. FM-screened or screened with a fine ruling, suffers less darkening than a conventionally screened tone area. When printing with yellow, which is a "light" colour, only a small decrease in lightness is to be expected with increasing ink layer thickness. In this case the curves for AM- and FM-screening are identical (Figure 1).

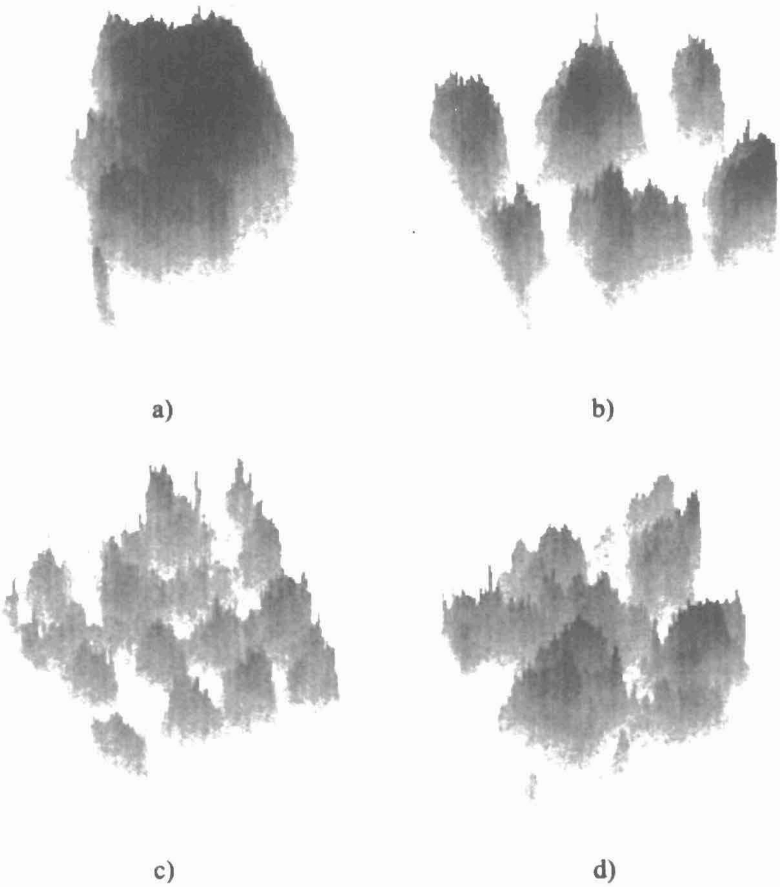

Figure 5: Local distribution of darkness on printed dots of different sizes
a) 60/cm, b) 120/cm, c) 240/cm, d) FM

In the course of a research project being carried out at FOGRA a micrographic analysis was performed on printed half tone areas using different screening techniques, and this has fully borne out the above conclusions. A three dimensional plot of the "darkening" vs. the local co-ordinates of the dots shown above

(Figure 4) clearly shows (Figures 5), that the big dot (a), which is taken from a conventionally screened 30 % half tone area, is much darker in the center than the small dots of the same half tone area screened at 240/cm (c) or after FM-screening (d). The latter also shows that where several dots run together darkening is greater.

The conclusion that a more homogenous ink layer distribution after FM-screening may cause a colour gamut improvement compared to conventional screening is also supported by results obtained from investigations of 3M-Matchprints produced using both screening techniques and also fine screen rulings. Colour measurements carried out on tone scale proofs did not reveal the above mentioned effect with either FM-screening or with finely ruled conventional screening (240/cm). Since a homogeneous coloured foil of equal thickness is used in the Matchprint proofing process the dots have the same thickness irrespective of the dot size (Figure 6).

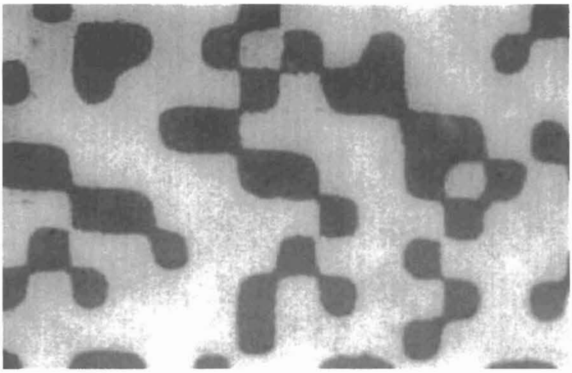

Figure 6: Dots of a 3M-Matchprint proof (dot percentage 30 %)

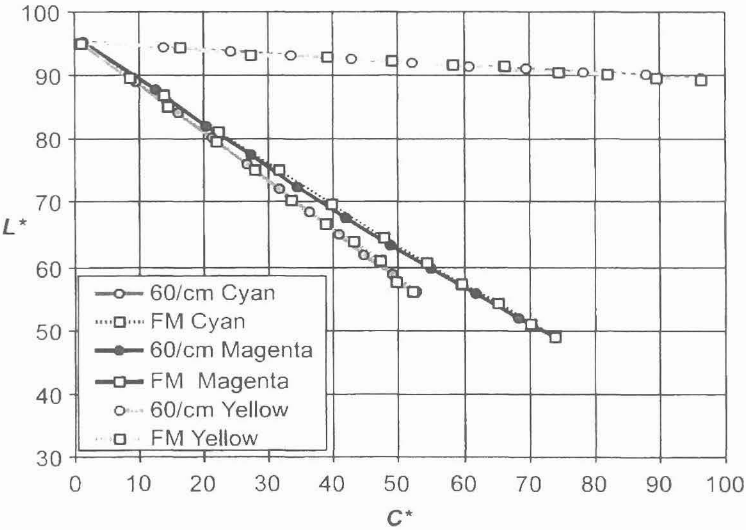

Figure 7: Lightness L* and chroma C* of tone scales proofed after AM- and FM-screening

As a result of this, and contrary to the situation in offset printing, there is no difference in layer thickness and hence in lightness between the centers and edges of dots conventionally screened at normal rulings. Given this conclusion, plots of L* vs. C* measured on Matchprint proofs of tone scales should not show any difference between AM- and FM-screening. Figure 7 shows that this is true.

It was mentioned above that the uneven distribution of ink on a printed dot is assumed to be a consequence of ink spitting in the roller nips of a press. Attempts were recently made at FOGRA to gain an insight into the occurrences in the nip.

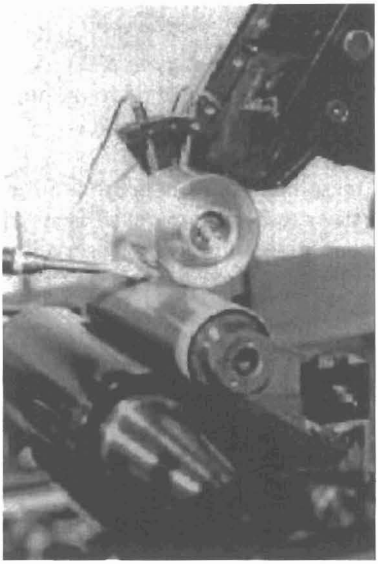

Figure 8: Laboratory roller system

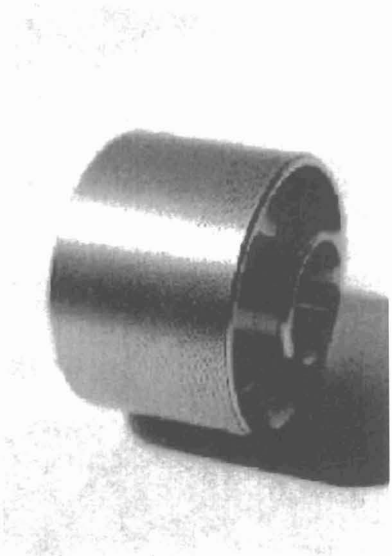

Figure 9: Offset plate roller

Microphotographic equipment including a three chip video camera and ultra short time flash illumination (600 ns) triggered with the cammera were used to record video sequences from the nip of a laboratory roller system (Figure 8) based on a commercial tackmeter equipped with an offset plate roller (Figure 9), a rubber roller and a dampening device.

Figure 10 shows a digitized still video of the splitting of an undampened ink film at surface speed of 50 m/min. Filaments being formed after splitting are randomly distributed over the whole area.

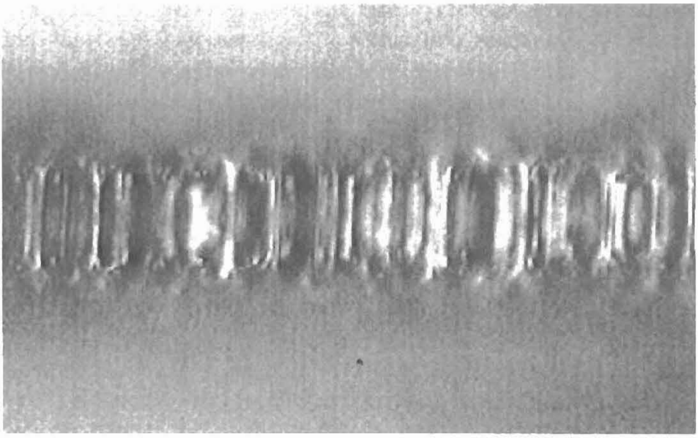

Figure 10: Splitting of an undampened ink film at a roller speed of 50 m/min.

The diameter of a single splitting spot under these conditions is approx. 50 µm which is similar to the results obtained in an earlier research project (Rosenberg, A., 1986) (Figure 11) when differently dampened ink films were observed by microphotography on a rotating acrylic glass roller using ultra high speed flash.

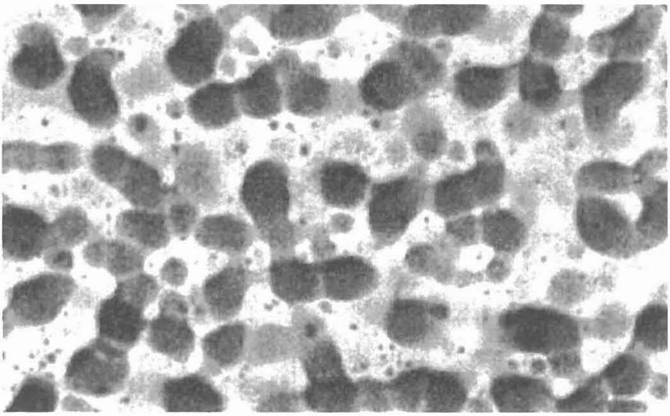

Figure 11: Undampened ink film 10 ms after splitting.

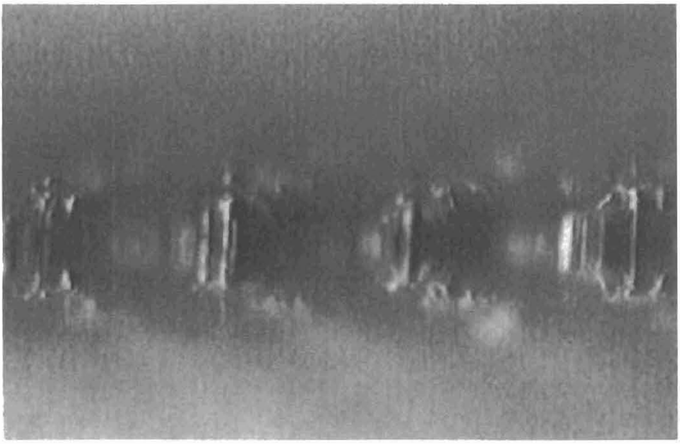

Figure 12: Splitting of the ink on dot (250 μm) after dampening at 50 m/min.

After dampening, the non image area of the plate runs free of ink and splitting occurs between the dots on the plate (upper side) and the rubber roller surface (Figure 12). The dots shown here are from a 20 % half tone area screened at a ruling of 20/cm. Such a coarse ruling was used to allow single dots to be observed during the microscopic analysis. What can be seen within the depth of field of the microphotographic system is a row of relatively large diameter dots (250 μm). Splitting of the ink film occurs on these dots in a similar fashion to that observed for a solid area (Figure 10), i.e. several splitting points and filaments are randomly distributed over the whole dot area.

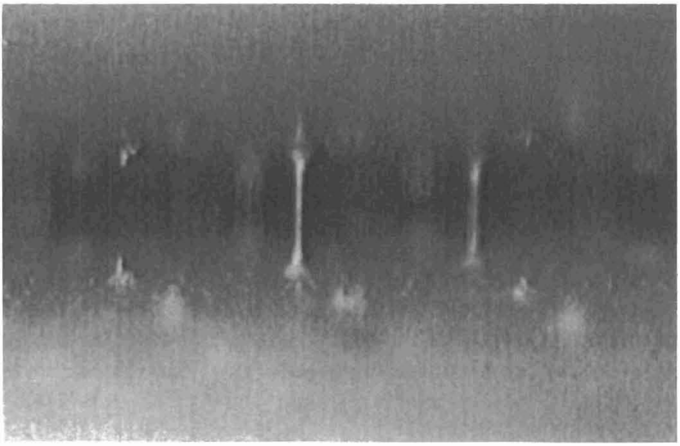

Figure 13: Splitting of the dampened ink on a dot (130 μm) at 50 m/min.

Looking at the dots in a 10 % half tone area (dot diameter: 130 µm), as expected, we observe a smaller number of splitting points and filaments on the single dots (Figure 13).

Doubling the roller speed to 100 m/min reduces the length of the filaments, which means that the splitting of the filaments happens earlier and/or deeper within the nip (Figure 14).

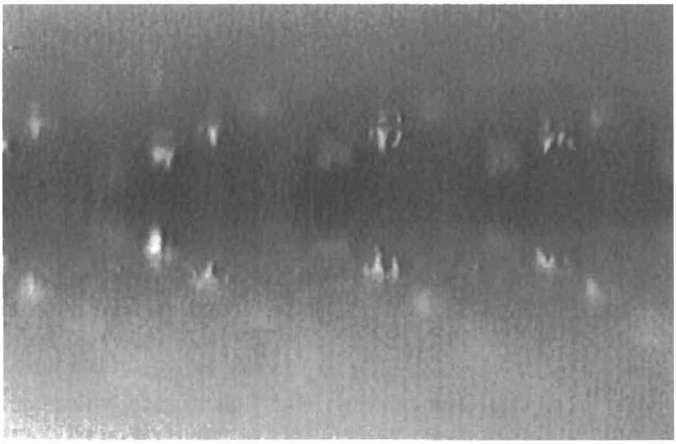

Figure 14: Splitting of the ink on a dot (130 µm) at 100 m/min.

Unfortunately, with the equipment available, it was not possible to observe the splitting process in areas of small dots such as those created by FM-screening for want of sufficient illumination of the inner nip. Therefore, all that can be stated from the actual results is that when the dots have diameters of less than about 50 µm, further reducing the size of the dots also reduces the size of the splitting points, and the accumulations formed on a single dot after the filaments split are also reduced in size. As a consequence, less ink accumulates on the dots and there is less darkening.

Therefore, if two printed areas with the same dot percentage are compared, one having been produced by conventional screening and one by FM-screening, the ink film thickness of the latter is lower and its distribution is more homogeneous. This produces less darkening of the printed colours and the colour gamut that can be produced by offset printing is improved.

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