The angles of AM screens

In halftone printing, the choice between moiré and colour drift is a decision between two evils

Prof Dr Martin Dreher

The angles of amplitude modulated screens (AM screens) is quite a current printing problem. Even so it hardly attracts the interest of experts and the solutions available are anything but satisfactory. However potential future developments could make this issue a major focus of concern.

The dilemma of halftone multi-colour printing

Most graphic printing methods use halftone printing. Gravure printing is an exception, but this process also runs in a semi-autotypical way today (variable depth gravure cells) and therefore is also the object of the following technical conditions.

Halftone printing processes only consist of two inking conditions: Inking of the image elements or non-inking (on/off; yes/no; binary) of the background. For the generation of halftones for the reproduction of printed images screening technologies are used. Comparable to the electronic image which is captured in pixels, the printing areas are split into small sub-areas, each provided with a degree of ink coverage according to the respective tonal value. This means: the lower the tonal value, the thinner the ink coverage.

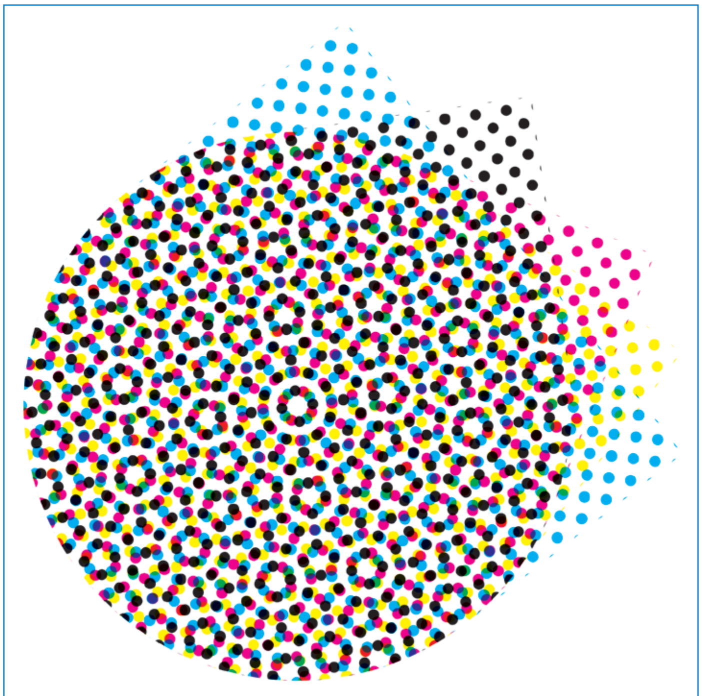
This level is determined by the positioning of individual, even-sized printing dots supposedly randomly distributed throughout the printing surface. This process is called frequency modulated screening (FM). However, the degree of ink coverage can also be achieved by using single, variable sized dots which is called amplitude modulated screening (AM). The variable dots are called halftone dots.

Frequency modulated screening offers many advantages in terms of the current problems. In practice, however, they have some serious disadvantages which have, as yet, prevented a wide scale technological breakthrough. Rather they are mainly used for special effects and require a higher degree of process control and care. The print quality achievable with this process is threatened by the appearance of a visually perceived graininess which results in mottling.

“AM screening dominates the current print market and offers the required smoothness in half-tone areas”

For these and other reasons, the amplitude modulated screening dominates the current print market and also offers the required smoothness within halftone areas and are therefore preferred by the client. AM screening means the arrangement of the screen dots in a regular and symmetric pattern. In multi-colour printing this involves the need to rotate the screens relative to each other, which is referred to as the screen angle. Otherwise, the overlap of the screen dots would cause interferences known as colour drift and/or moiré.

In practice, this can lead to severe colour changes of the consecutively printed results. This is caused by the fact, that when the dots from a single colour meet on the substrate the corresponding dots only partially overlap depending on the image tone. If this degree of overlap changes by even a small amount due to unavoidable register fluctuations, changes in



Source: DFTA-TZ

Figure 1: Current screen angles in four-colour halftone printing

the colour tone will result. Colour drift (or shift) can therefore be interpreted as interference or Moiré, which means that the typical interference pattern only occurs infrequently, but in practice only once.

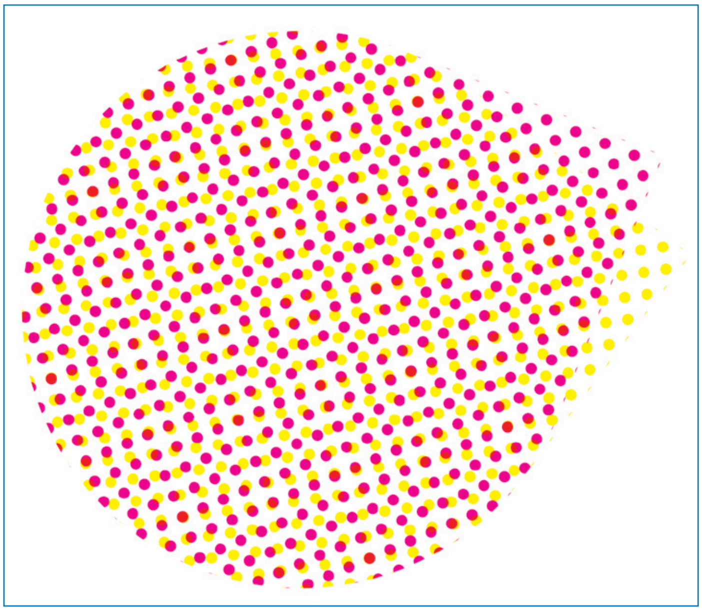
If a small rotation of the screens is made as a counter-measure, the interference initially decreases more and more rapidly, reaching a noticeable and thus disturbing order of magnitude of a few millimetres and passes through a minimal degree of visual disturbance at angles between 30° and 60° of rotation. From then on the interference increases to a disturbing level. On the premise that as many angles as possible for single colours should be used, this explains the choice of the 30° screen angle which is currently the preferred choice in the printing market.

Perceptible moiré patterns must be avoided as they significantly impact on the appearance of the printed image. However, the current technology status limits the rotation of the screen as a counter-measure. This is explained by the need to rotate the screens by 30° each, however only three options are available. Due to the symmetrical shape of the screen the total range of angles is limited to 90°, which allows only three "clean" angles with 30'° rotation per colour. However, multicolour printing generally uses the four colours cyan, magenta, yellow and black (CMYK).

It has already been tried in the past, to extend the available range of screen angles e.g. by using dots with an elliptical shape, however this distortion changes the amount of overlap of the dots. Although this gradually reduces the tendency for colour drifting, it does not solve the problem of fewer screen angles being available.

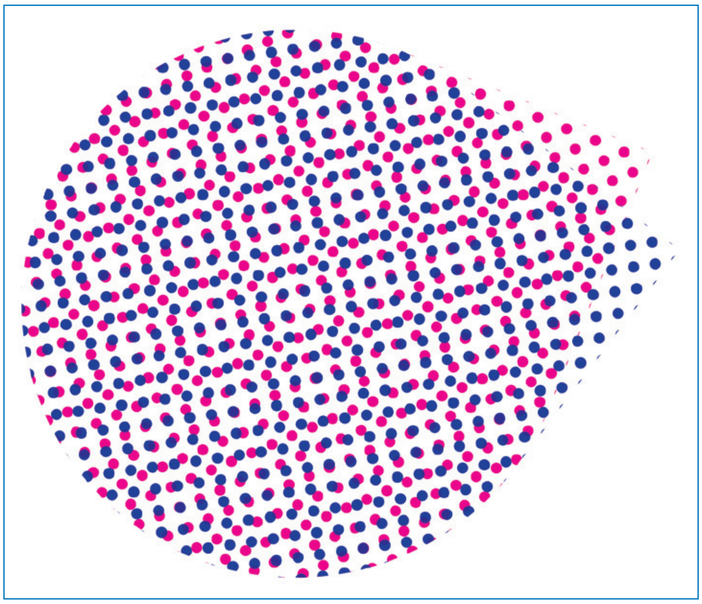
The "fake" solution

In current printing practice, this problem is "solved" by placing the bright and low contrast colour yellow halfway between the standard angles of the other two colours. (figure 1) This means that the angle rotation of the yellow is only 15°, which inevitably results in moiré. (figure 2 and 3)



Source: DFTA-TZ

Figure 2: Yellow moiré



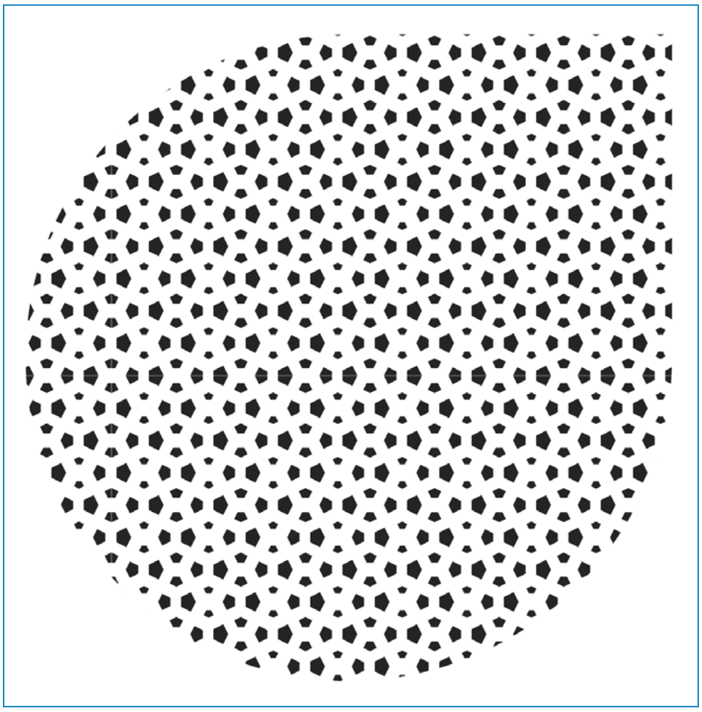
Source: DFTA-TZ

Figure 3: Yellow moiré after colour change into violet blue

However as this is so weak visually it does not affect the visual impact of the printed image as stronger colours "hide" the effects. In particular the mixture of yellow with the other colours has a slight effect on the end result with a slight moiré pattern The reduction in print quality by the yellow moiré would be even further accentuated, for example, when the currently much discussed issue of fixed palette printing with seven process colours isused to enable production costs to be reduced. It must therefore be assumed, that this promising approach will either fail due to the yellow moiré or at least its potential for cost savings will be reduced significantly. Given the circumstances described above, seven colour printing with amplitude modulated screens can only be used under certain conditions.

For this purpose the same screen angles must be used twice with the respective complementary colours positioned at the same screen angle. Such complementary colour pairings are magenta and green; cyan and red; yellow and violet blue. Provided that both complementary colours do not occur at the same time at the image – which for printed photographs is ensured through the GCR colour separation – both moiré and colour drift can be avoided in theory.

In practice with this theoretical approach, weak points such as



Source: DFTA-TZ

Figure 4: The DFTA Screen V6 Penta

"yellow moiré" or "violet blue moiré" can occur. If the moiré caused by yellow together with its neighbouring angle is barely visible (figure 2), it is clearly visible on the same angle as yellow when violet blue is used (figure 3). To solve this problem, it may be possible to intervene in the graphic file to allocate the respective functional angle combinations in a job related way. However this would be associated with the manual drawing of masks which means extra undesired effort. In this context, automation does not appear to be possible.

Is there a "real" solution?

The aforementioned "visual cover-up" of the problem due to the limited possibilities of screen angles and the accepting of yellow moiré will fail when attempting to print with process colours comprising more than three colours. This may be the case with seven-colour-printing, but it can also be a challenge when using screened special colours. In this context, the assumption is plausible that the current yellow moiré is responsible for some supposedly inexplicable phenomena in colour matching, for example between proof and print.

As already pointed out, the use of frequency modulated screens is not a "real" solution to the present problem. Since these screens have no regular structure, no moiré can occur. This makes it possible to "allow" more than three colours to appear at the same time on each printed image. Since all seven (or more) single colours can be screened independently, an FM seven-colour-printing is no longer tied to an achromatic (GCR) colour separation, however it has certain limitations making it not suitable for all applications. However, this does change the already described disadvantages of FM screening, which is why it cannot be considered a universal solution.

A small print mistake caused the author of this article consider other solutions to the described dilemma. During the course of a student project the situation arose because of an interpretation error where the colour separations for cyan and yellow were allocated the same screen angle with the same screen ruling. Surprisingly, this had no negative impact on the printed image but was discovered by a fortunate coincidence. From this "mistake" came the idea to position two individual colours from the four colour set at the same screen angle. However, as a colour drift was to be expected, this process had to be thoroughly analysed within a further project before presenting it as a "real" solution.

Figure 4 indicates the print results from this analysis. Single colours were screened with the same angles, with 50% and a 25% screen values as a visual aid. Particularly revealing is the respective comparison in the directions "North/West" versus "South/East". These colour fields located to the left and right of the a diagonal running from bottom left to top right all have the same composition – but once with and once without the usual screen angle.

The upper square contains the four single CMYK colours. The underlying colour areas below the diagonal have a much bluer appearance than their counterparts. Technically this is explained by the fact, that when fully covering all the halftone dots with the next single colour, the peculiarities of ink trapping and transparency had a full impact. Any omission of any screen angle, ie the rotation of all the single colours on the same angle, is not possible because it gives a strong blue tint.

On the other hand the combination of cyan and magenta at the same angle gives a much smaller colour difference along the diagonal and could therefore be considered as a usable process. A comparison of the other squares shows that the third square (C + Y) and the last square (Y + K) perform even better.

Does this mean, that cyan and black or black and yellow respectively can be set at the same screen angle? Unfortunately, this cannot be decided on the basis of the results so far, since a colour drift may

Source: DFTA-TZ

Colour combinations with/ without screen angle rotation occur as a result of using the same angles for two different inks. Therefore, verification in this area still requires many more print test runs. This study was carried out at the DFTA Technology Centre. The DFTA-TZ came to the conclusion that the colour drift actually has a disturbing effect under these circumstances. The samples showed such strong colour deviations, that no customer would accept such a product. Thus, the idea of using identical angles for different colours had to be rejected.

At the beginning of 2018 however, another solution to the problem was discovered in the form of a halftone screen which had previously been developed by the DFTA-TZ. Although the Screen V6 Penta always attracted attention due to its visual harmony, it was considered useless for screen angles because of its peculiar shape and the arrangement of the screen dots. However, this was based on the traditional way of thinking for example only applying a rotation of 30° which turned out to be unsuccessful with this method of screening. This changed by only making quarter turns, although this doesn't make sense with AM screens because of the predominate dot symmetry. In this case, however, the interleaved dot arrangement resulted in new results with every quarter turn.

In the course of further investigations, not yet completed, it was also shown that the Penta screen maintains it's relative insensitivity to colour drifting even with a 90° rotation. Therefore, it is quite possible, that this represents a second solution to the dilemma described – perhaps even the better of the two. Because of its many advantages, this screen has been filed for a patent application.

Summary

The current practice of using amplitude modulated screen angles (AM) results in yellow moiré as there are not enough screen angles available for all four process colours. Yellow moiré seems already to be responsible for several printing problems, but becomes a real problem when using more than four colours. This not only relates to seven-colour-printing but also to special colours. Although the use of FM screens is a solution to the problem of lack of available angles it has so far not been successful because of its disadvantages.

A second solution was surprisingly found in the form of the DFTA Screen V6 Penta, which is currently being investigated further. The currently available technologies, including the yellow moiré, only offers the choice between two evils: moiré or colour drifting. Overcoming this unsatisfactory situation seems to be highly desirable as far as the further development of all halftone printing processes are concerned, be they offset, flexo or digital.