Dot Gain in Offset Printing

The increase of screen dot sizes in offset printing has two basic reasons: One is a characteristic of the lithographic printing technique and based on the competition of two liquids to wet the plate surface. The other one is caused by mechanical action between cylinders. In addition to that in screen areas we find higher color intensity than we would expect only from area coverage. This part of dot gain is due to light gathering below the dots.

The PSO (process standard offset) gives noteworthy dot gains for printing screen dots, if we compare film or data values as aims and the prints as results. Anyhow this well-thought-out target shows that we do not have processing defects here, but typical properties of technical processes.

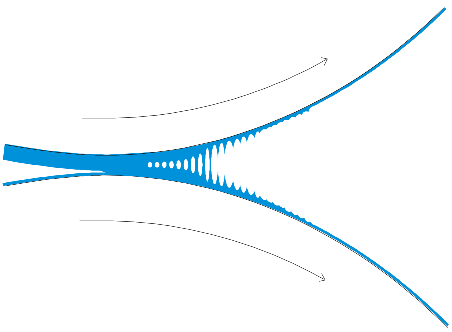
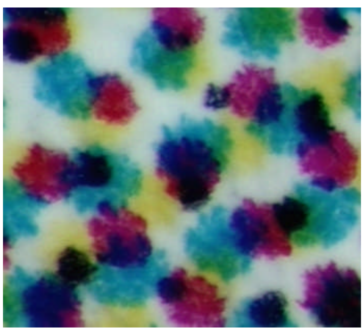
A gap between old and new machinery.
For decades suppliers and printers have done their best to reduce these dot gains. They have been developers of presses, rollers, rubber blankets, printing plates, inks and fount concentrates. Today all the development work has led to the funny situation that printers with a new machine find the contrary: If they intend to fulfill the specifications of the PSO, they must use a lot of tricks to bring the dot gain up to the specified level, at least on high class paper qualities. In commercial practice there is a big gap in working with old and new equipment.

Technical terms.
In press rooms there is interest only in the total change as a sum. Under economic and technical aims it is important only how to produce high quality prints from data or reproductions. But as soon as for quality reasons we try to adjust our machinery to standards like the PSO, it is useful to look, which component influences the dot distortion, and how it does. So in the following we observe dot shape and size on its way from the plate to its optical impression of the ready print.

Our technical literature simplifies the situation and defines a “mechanical gain“. That means the dots are mechanically squeezed between plate and rubber cylinder first, and rubber and pressure cylinder (including paper) second. On most printing materials common authors add light gathering, an additional color outcome by light caught in the paper under the screen dots. This model is poor, because it ignores of all influences that of the lithographic process.

Formerly we used the expression „optically effective area coverage”. For many times this helped only the mix-up with “area coverage”, and still many people in practice see it that way. Now the official technical term is “tonal value”. It does not say, which kind of action does the effect, and thus it includes both, geometrical and optical influences.

What happens in the press?
If we have a closer look into it, it starts on the plate with rasterized half tones. The area coverage of screen areas is nowadays easily measurable by video-analytical devices. In practice we start with film or data measures, but for this discussion only the plate situation counts.
Often the technical literature treats the ink layer of the dots as uniformly thick, like small plates. By film splitting after the inking rollers quite craggy surfaces are formed, more comparable to mountainous islands than plates. These crags will become rather more uneven than balanced with every following nip.

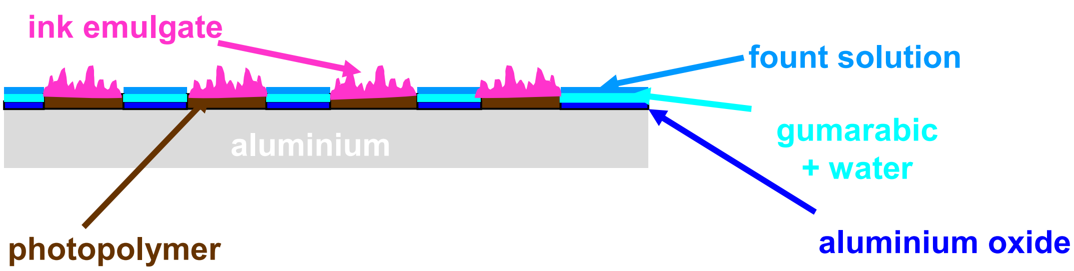



Pict. 1, Film splitting after the nips leaves an uneven, craggy dot surface

The part of the offset plate process.
In the moment of inking the image areas, the first step of deformation takes place: In general it is true that the ink covers the printing elements of the plate. If the non-image-areas however are not thoroughly wetted by fount solution, the ink will expand across the borders to cover more surface than intended. All the time ink and fount solution compete in covering plate surface. This is the offset specific share to the total dot gain, the characteristic part of the wet offset process. It is susceptible to many parameters among ink and fount solution. For instance high percentage screen areas tend to fill up at pH values of 5.3 or higher, more often with magenta or yellow than with cyan. Water softeners in ink or fount cause the contrary.
The competition in covering plate area is dynamic: tiny local changes of fount solution are typical for the lithographic process while running. This is one of the reasons, why screen areas never will print strictly constantly, but always vary a little over the whole printing job.

In this competition not only wetting processes have their influences, but also rheological aspects. Viscosity and especially the tack of the transferred ink-fount-emulsion react very sensitively with small changes in proportions. So both aspects are important, surface tension and flow behavior.

We know that in conventional lithography screen fineness is limited to about 120 l/cm. Finer screens loose tonal gamut, because small dots are not clearly printed, and small holes are filled up. However, the same machine, used with a waterless plate and without fount, can easily print much finer screens - up to 300 l/cm are reported. The only difference here is the lithographic process. The mechanical dot gain share still exists. But we do not find the additional lithographic reason for dots spreading.



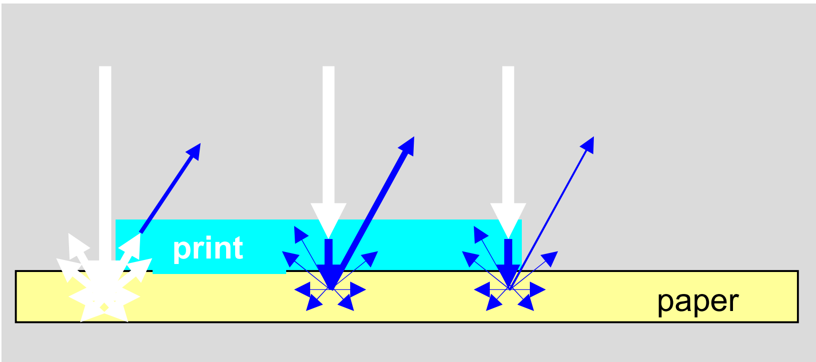
Pict. 2, The ink permanently tries to push the fount solution over the dot borders.

Plate materials of image areas play an important role in the process of dot size forming. There are photopolymers (in diazo plates), other organic layers (e. g. thermal plates), silver containing materials (silver diffusion plates) or even copper as a metal (bimetal plates). Each one of them has its own influence on dot gain.
What does it help to know about this overinking? It tells which setscrew to adjust, if dot transfer must be controlled. Nobody would change plate type any more without controlling the characteristic diagram. Changing the fount concentrate can change it. Who thought about that, when he only intended to reduce isopropanol consumption?

The mechanical part.
In the next step the ink passes from the plate to the rubber cylinder. In this nip the ink will for sure not only flow and disperse the dot a little. This simple model should be left, because it is not a typical liquid between two hard surfaces. There is about 2 to 4 µm of ink layer between a smooth plate and a rubber blanket with topographic structures from 1 to 15 µm of depth. In every nip there is always a hard and a compressible partner. The compressible partner is impressed and hereby deformed. This makes the dots spread to some extent. It is stretched and compressed. And after every nip the dot is ragged.

In the mechanical step of dot gain flowing and splitting movements play the main role. They are susceptible not only to the force giving elements like plate and blanket, but also highly to viscosity and tack of the transferred ink-fount-emulsion. And by the way, the topography and compression characteristics of the blanket are crucial.
One of the mechanical actions is the transfer from blanket to paper. The softer the paper is, the more it will be compressed and deformed. The dot is now much more ragged than after the nips before. It must set upon a surface with a much bigger roughness than its own thickness could fill or compensate. With a lens or a weak microscope we can see, what happened to such a dot. It is not even necessary to print on uncoated paper for such deformations. A glossy coated art paper is enough to belie our statement to beginners, if we tell them an offset dot is evenly colored and neatly edged.
Once transferred the ink dot has to set. Under the high sheer forces of the last nip contact the ink has a low viscosity, because it is pseudoplastic (sheer thinning). In an instant the viscosity will rise and the beginning penetration of the thinners intensify this change up to the immobile state. Gloss inks flow for some more moments to form an even surface. Quick setting inks will keep some roughness from the ink film splitting process.

Paper and light gathering.
Up to this point we have looked at the shape and size of the screen dots, their geometry and topography. For a thorough understanding now we must consider a phenomenon, which can bring as much influence on color effect as both others together. And it depends on many things - but never on the printer or the press. It does exist even in flexography, gravure printing, or the old letter press. It is due to properties of the typical printing material in offset, to the paper material.
Paper lets light intrude between its fiber work and scatters it. By this it gives us the impression of a white, bright surface. A raster dot upon such a surface will gain some additional optical effect by the penetration of light below it. This effect is called light gathering, sometimes Yule-Nielsen-effect.



Pict. 3, Draft to explain light gathering

Rays of light, which come close beneath a dot into paper, are scattered. If such a scattered ray falls into the direction of our eye or densitometer, it will pass the ink layer first and hence become colored by losing some wavelengths through absorption. According to the place of intrusion they should be colorless. But so they increase the color effect of the dot.
Opposite to this position another light ray will fall through ink layer, then be scattered in the paper, and finally leave into observer direction directly out of paper. It will have a deficit of color effect, if counted for inked surface. Both effects do not exactly compensate each other, because the original ray of white light in the first case is stronger, and penetrates deeper than the weakened (by absorption with its first pass through the ink layer) ray. So the first ray will produce more scattered light than the second one, and we have a total increase of color effect.

Screen construction and light gathering.
It is clear that light gathering depends on paper, because uncoated paper allows deeper light penetration than coated, and so on. However the effect highly depends on the sum of edge lengths of dots. It is understandable, that light gathering increases with screen fineness or dot size, e. g. in non-periodic screens.

As an example we compare two similar screens. Both have circled dots, one with 60 lines/cm, and the other with 80. With exactly the same area coverage the finer screen will exhibit a bigger color effect (optical density, color intensity) than the coarse one. It will not be wrong to say that popular all non-periodic screens (FM sceens) are fine screens, because they use rather small dot units. Indeed in their beginning there was told they reduce ink consumption. Today we know that this small advantage is negligible compared to the expansion of the color gamut of halftone printing caused by light gathering. Light gathering makes the difference between the old “area coverage” and the actual “tonal value”. According to paper (or board) quality and screen type it may contribute more than 10% to the dot gain in offset printing. Clearly it is a main component in calculation.
Even some plastic materials allow the light to intrude below the dots, if printed. On the other hand there are metalized paper qualities (e. g. in label printing) with direct reflection exclusively, thus without light gathering share in tonal value increase.

Summary.
For our actual knowledge tonal value increase in offset printing is allocatable to three processes:

- One is bound to the lithographic process with ink and fount.
- Another is understood with mechanical actions in the transfer of ink emulsion from plate to paper.
- The third increase of color effect is light gathering below raster dots.

Each of these steps has its own characteristics and offers possibilities to control the characteristic curves of the offset printing processes.

Bergheim, 1st January, 2010