Inks for Digital Offset Printing

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Abstract

On DRUPA 2000, digital offset printing presented itself to be a highly innovative field within offset technology.

Since conventional printing inks could not satisfy the physical or chemical needs new products had to be developed. The following requirements were to be met:

- Being competitive to conventional offset regarding print quality
- Optimum performance on the specific digital presses
- Supporting all advantages of a digital press

This paper simplifies the complexity of high-end ink technology. Some basic principles are described for better comprehension of the rheological behavior of ink on press.

Some digital offset presses are listed and it is explained how printing ink systems are realized to optimize press performance.

Introduction

Offset printing is one of the most versatile printing techniques. It is both competitive in small jobs and in longer runs. Relative to other technologies pre-press costs are comparably small, so, offset printing is the preferred technique for small to mid-size job length.

Offset printing is, by far, the most advanced printing technology concerning standardization. The link to digital interfaces is given allowing Computer-to-Plate or even Computer-to-Print workflow.

Therefore it is more than logical that offset printing and press technology is the first choice for high-end digital printing.

On the other hand, toner-based digital printing is developed. This technology is not understood as offset printing and will not be discussed in this article.

General

The principle of offset printing has been described at numerous places. A thorough scientific explanation is given in reference 1. Lithography is a planographic process. The image and non-image areas are in the same plane on the printing image carrier. Chemical treatments are used to ensure that the ink adheres to some areas and not others. That is, the effect of the treatment is to create areas of different surface energy on the plate. This results in image areas that are water repellent and ink accepting, and non-image areas that are water accepting. Thus, the plate is usually damped before it is inked.

The process is called offset lithography because the inked image on the plate does not print directly on the paper, but it is first "offset" onto a rubber blanket, and thence transferred to paper.

Whilst straight water was used in the beginning it has been seen that additives as alcohols (Isopropanol) improve the lithographic behavior. Nowadays, fountain solutions are offered to the market to replace tap water for the dampening process.

Waterless Offset Printing

There have been numerous approaches to establish planographic lithography without the use of a fountain solution. The first patent was claimed in 1970 (see reference 2).

Even though waterless offset is a well established printing technology it is not yet fully understood in the sense of physical and chemical interaction of printing ink and printing plate. There are 3 criterions ruling the adhesion or repulsion of ink on the image or non-image areas.

- Surface energy of plate and printing ink
- Viscous flow considerations
- The weak fluid boundary layer model (WFBL)

These aspects are discussed in reference 3. Whilst surface energy is a basic requirement of the process (see reference 4), the WFBL model may explain most of today's observations on press.

A simple experiment might explain this model (reference 5): Printing ink (formulated for waterless printing) is applied by a rubber roller on an appropriate waterless printing plate. After a single stroke ink adheres on the image and on the non-image areas as well. By repetitive application with the same roller the ink is repelled from the non-image areas providing a situation ready for print.

Under the shear force of the roller ink solvent is segregated forming an additional liquid phase. By continuous stress the disintegrated ink solvent is partially absorbed by the ink vehicle again. It can be assumed that a steady state situation is achieved.

If an offset vehicle is sheared the optical appearance changes from clear transparent to dull. This is explained by segregation of ink oils and underlines the WFBL assumption. Vehicles for waterless inks show a stronger effect than others.

This free ink oil is then absorbed by the top layer of the non-image areas of the plate. Once this top layer is saturated with ink oil repetitive stress by the roller causes the oil to be "squeezed" out. The free oil protects the ink to wet the surface and undergoes the splitting. This is analogous to conventional offset where low viscous fountain solution is split in the nip rather than high viscous printing ink. There is the term of "internal dampening".

If the system plate/ink is not able to keep the non-image areas clean printing is not possible. This defect, called "scumming" or "background toning" is absolutely crucial for waterless printing.

Rheology of Printing Inks

The performance of printing inks on digital and conventional offset presses is clearly dominated by their flow properties (rheology). Printing inks do have a very complex rheology, mainly for 2 reasons. Firstly, the resins and the ink oils form a colloidal phase when cooked at temperatures up to 240 °C. This ink vehicle containing resin and oils in comparable percentage does not represent a clear solution in the physical chemical sense. Secondly, insoluble pigments used as colorants are being dispersed forming an additional solid phase. Both effects lead to a strong non-ideal rheological behavior, which is essential to be understood when discussing press phenomenons as ink transport, screen reproduction or waterless printing.

The key parameter of rheology is viscosity as the relation of shear stress to shear rate. Printing inks do not have a constant viscosity over the entire shear stress range. Their behavior is called pseudo-plastic, which means that the apparent viscosity increases by decreasing the shear stress (reference 6).

In the printing process the shear stress varies over a wide range. The lowest shear stress is the free flow caused by gravity in the ink duct. Depending on the angle of the duct plate shear rate can be assumed to 0.1 to 1 s^{-1}. Highest shear rate appears in the nip of ink rollers (reference 7) and is quoted to exceed 10 000 s^{-1}. This estimate refers to an ink train of a classical offset press consisting of soft/hard roller pairs. One can assume that high viscous offset ink sheared in a keyless anilox system undergoes even higher shear rates. Thus, shear rate in the specific steps of ink transport in an offset press varies by 4 to 5 orders of magnitude.

There is no test device being able to measure the entire shear stress (or shear rate) range. The preferred instrumental technique, rotational viscometers (reference 8), are capable to cover reproducibly the mid range from approx. 3 to 300 s^{-1} without major systematical errors. Limiting factors are the behavior of the ink in the cone/plate (or plate/plate) gap and the design of the instrument itself.

Below 3 s^{-1} a tilted plate (30°, 45° or 60°) is applied to measure the free flow under the influence of gravity. The length is recorded which the ink goes in a fixed period of time.

The range from 50 to 2000 s^{-1} is covered by Falling Rod Viscometers. They are widely used in the printing ink industry. Test procedures are described in national and international standards (reference 9)

Beyond 2000 s^{-1} capillary viscometers might be used. Unfortunately, there is little experience reported about the application of this technology on offset printing inks.

In general, print tests on presses clearly indicate the performance of printing ink under high shear force (shear rate). Criterion is usually the ease of reaching standard optical densities on the print over a wide press speed range.

Sometimes oscillatory tests give a clue on the performance of ink at higher shear forces. These experiments are carried out on rotational viscometers at increasing circular frequency at fixed amplitude. So, the elastic and plastic component of apparent viscosity (G' and G") can be calculated. The loss factor tan δ = G' /G" indicates the break-down of structure at increased shear. Beyond a specific level the ink vehicle loses elasticity and will be poorly transported on press. Consequently, it is desired to have a stable (flat) graph of tan δ over a wide range of rotational frequency. For further detail see reference 7.

In case of "wet" lithography the latter test can be modified for ink/fountain solution emulsions as well. Very helpful information is obtained about emulsion stability under press conditions. The crucial point is the reproducible preparation of the sample itself. Droplet size and distribution are the key factors for a reliable test result.

Thixotropy

Thixotropy is given if viscosity decreases when being sheared. This phenomenon is time-depending and shows significant hysteresis. It is explained by the break of structure with shearing time. Leaving the sample still, structure will recover.

Thixotropic inks show poor flow at low shear rates. This might lead to defects in ink supply ("hanging back" in the conventional ink duct) or pump problems if ink is supplied from cartridges. So, in contradiction to coatings where this effect is often meant, thixotropy of printing inks is avoided as far as possible.

Rheological studies on printing inks require identical treatment of the sample. This assures that potential thixotropy does not interfere with the measurement itself or – if desired – is not broken before the measurement starts.

Influence of Temperature

All flow parameters are strongly temperature dependent. A thumb rule says, that the viscosity of an offset ink decreases by 10 % if temperature increases from 23 °C to 24 °C (reference 10). Even by the use of high structured resins of latest technology this gradient is still at the range of 5 – 8 % per °C at room temperature.

Consequently, modern presses assure constant temperature conditions at least in the critical steps of ink transport.

In the case of waterless printing, care is taken to keep the printing plate within a specific temperature range. Optimum plate temperature varies from press to press and from ink to ink, even within a 4 color set. In practice, it is evaluated by systematical press trial before printing.

The reason is, background toning (see above) strongly relates to the temperature of the plate during printing. This is explained by the loss of viscosity with increased temperature. A less viscous ink is sheared to a minor extent and disintegrates less ink oil available for the non-image areas to be kept clean. Secondly, temperature has an effect on the solubility parameters. This is explained in detail in reference 11.

A Critical Toning Index (CTI) has been established to describe this phenomenon (see reference 12). It is worthwhile to state that the CTI is not a factor solely depending on the composition of the printing ink. It is furthermore a complex parameter given by the plate used and the experimental set-up. Press speed and the pressure of the ink form rollers play the dominant role ruling the CTI besides the ink itself. Using CTI measurement for printing ink studies thus requires absolute constancy in the experimental set-up.

Printing inks with high CTI value are less prone to background toning in practice. For oil-based waterless inks, this is achieved by higher ink viscosities and lower tacks (see below) compared to conventional lithographic inks (reference 13).

Tack

Since the flow property of printing ink is rather complex it has been the desire to establish a parameter which is press related and easy to reproduce in the laboratory as well.

The tack, as recorded on a rotational tackmeter, is the drag force between two rotating rollers caused by the presence of an ink layer on their surfaces (reference 14). This drag force is mainly determined by the shear stress and the corresponding pressure profile in the converging zone of the nip. A probably much smaller contribution stems from the splitting of the ink layer.

Consequently, for ink studies the entire design of the instrument and the environmental conditions must be kept constant. The machine parameters set to zero, the drag force is given by the adhesion of the ink on the rollers, roller speed and the cohesion of the ink itself. Additional parameters as temperature, ink volume applied, aging of the rollers will not be discussed here.

From the aforesaid it can be concluded that the tack is not an ink property as such. However, since a rotational tackmeter is able to simulate a printing press – or parts of it – a tack reading is a helpful number to explain specific phenomenons of ink on press.

Tack readings on instruments of different design cannot be converted by simple calculation. For attempts see reference 14.

The tack reading has the dimension of a force whereas this is mostly neglected. Within the same ink chemistry and all other parameters kept constant one can attribute the tack to the ink itself pretending to be a physical property. In fact, ink chemists use the tack as a very helpful parameter, and, with the experience over years, they are capable of predicting some aspects of press performance by the tack.

The use of rotational viscometers is a subject of an ISO standard (reference 15).

All rheological instruments used (tackmeter, viscometer) are listed in reference 16.

Digital Offset Presses

In the following some digital offset presses are listed. Please see comment in reference 17.

The common feature is the preparation of the printing form in the press itself via a digital interface

1. DICO-O-WEB (MAN Roland); web offset heatset press equipped with an erasable printing cylinder
2. Speedmaster DI 74 (Heidelberg); conventional wet lithography
3. Quickmaster DI 46-4 (Heidelberg); waterless printing
4. 74 Karat (Karat Digital Press); anilox ink train, waterless printing

Experiences with other presses of this category is not available yet.

Inks for Digital Offset Presses

All presses 1. to 4. were shown on DRUPA with printing inks from SunChemical (reference 18).

ad 1.:

The DICO-O-WEB process is a "wet" lithographic process. It requires a heatset ink with excellent ink transfer. Ink chemistry and rheological properties are in the standard range.

ad 2.:

Speedmaster DI 74 is based on wet lithography as well. The type of plate used requires ink with high ink/water stability. Printing inks based on pigment flushes (see reference 19) are preferred.

ad 3.:

The Quickmaster DI press can be run with 2 different types of printing inks: Oil-based and water-based.

The oil based product series is similar to standard waterless inks. Good ink transfer at moderate tack levels can be achieved. Inks based on pigment flushes seem to perform better.

The water-based system is a revolutionary technology. Therefore it will be outlined in more detail.

In general, the use of water as ink solvent has been considered earlier. However, evaporation of the water in the long ink train always led to a raise in tack and to premature ink drying.

The new system meets the following technical requirements:

1. The water is stabilized in the ink. Ink drying due to water evaporation is chemically hindered. No major tack raise in the ink train is seen, because of the absence of low boiling solvents and the stabilization of the water itself. Tack curves vs.

time are extremely flat and indicate outstanding press stability.
2. Setting is very quick due to fast penetration in the paper. The release of the water (= solvent !) by the vehicle is easier than in oil-based systems. The ink film dries faster and is less tacky during the drying process compared to conventional.
3. Set-off to the upper sheet is practically eliminated, permitting printing without spray powder. This is a huge improvement for the printers' environment and reduces the gloss loss.
4. On offset prints spray powder can be felt manually when touching the surface of the image areas. The elimination of spray powder and the absence of the petroleum distillate smell provides a more "sympathetic" perception by the consumer (end-user).
5. The rub resistance of the print is dramatically improved. The print can be processed (cutting, folding, bookbindery) much earlier.
6. Optical densities in the solids and dot gain in the screen compare to standard ink systems.

ad 4.:

The 74 Karat is a hybrid of various technologies. It combines

- ink supply from 2 kg cartridges
- the short keyless anilox ink train (used in flexographic printing)
- waterless printing
- Computer-to-press technology and
- high quality offset printing

This is an outstanding challenge for ink rheology. The ink must

a) show a reasonable flow through the narrow opening of the cartridge under very low shear stress
b) have excellent press stability on the anilox roller
c) have good ink transfer in and out of the cells of the anilox roller
d) not break the structure under the enormous shear of the chamber doctor blade
e) have proper "waterless" rheology.

Ideally, a) requires a "thin" low viscous ink, b) and c) need a high and time-stable tack level. d) should show even tan δ at high oscillations. High CTI level for e) is best achieved with low tack / high viscous inks (see above).

By use of high molecular weight resins with specifically limited oil solubility and the selection of high boiling distillates all these requirements were met. Inks based on pigment flushes are again preferred to those based on traditional dry powder pigments.

Conclusion

Inks for the new digital offset presses require vehicle systems with outstanding rheological properties. This is realized by thorough application of viscometers and by establishing flow models for improved understanding of the phenomenon ink flow. Open co-operation with other partners of the graphic arts industry as press and plate manufacturers is mandatory to guarantee success.

Finally, digital offset printing will play an important role in future besides conventional printing and toner-based electrographic technology. High-end ink technology enables profitability at a high print quality level.

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17. The list is not complete. It is not the scope of this paper to discuss concept and design of printing presses. Therefore, design details are mentioned only if important for the property of the printing ink. The fact of being mentioned and the order of the listing is arbitrary and does not reflect the quality or the commercial importance of the manufacturer or of the press itself. Addresses of the press manufacturer are available through the author.
18. Further chemical or commercial details on the printing inks are available through the author.

19. Flushes are pigment preparations providing a sharp pigment particle size distribution in the ink. This leads to excellent ink transfer and low plate wear.

Biography

Bernhard Fritz is with SunChemical since 1985. He started as research chemist investigating ink / water interactions. From 1987 he spent 2 years in SunChemical's plant for flexographic and gravure inks before returning to the Frankfurt central sheetfed ink laboratory. Today, he is Technical Director for European sheetfed ink development. He studied chemistry in Karlsruhe and Göttingen. He holds a Diploma and a Ph.D. in Chemical Kinetics.