Printing Ink Technology-Past, Present, Future

Robert W. Bassemir*

Keywords: Ink, Ink Technology, Future, Printing

Abstract: A review of the progress in printing ink technology during the past 60 years, a look at the present state of the art and science; and the impact of the challenges and innovations that are certain to bring important changes to the ink industry and the Graphic Arts in the new millennium is presented.

Introduction

During the last 60 years, printing ink technology has changed dramatically,influenced largely by the development of a number of different drying methods. Some of these inks were made in response to the availability of new printing and/or drying equipment, while others were invented before the necessary equipment had been developed. Most of these ink systems and the new equipment available led to the growth of new markets and created new applications and products. A summary of these significant developments will be given and their current status evaluated. The present state-of-the-art in printing ink technology in various printing methods will then be presented in light of new

*Inktec Consultations

equipment being used in both publication and packaging. An attempt will then be made to predict what kind of ink technologies need to be created during the next decade in response to the rapid changes in electronics, computing, optics and their combinations with mechanical imaging equipment.

Review of Past Technology

Most of the time the printing method or equipment and the type of product produced will determine the type of ink required. In some cases, a new or revolutionary ink has caused a new type of printing equipment to be developed. In many cases, new ink drying or setting mechanisms have generated a new market and new printing and drying equipment needed to be created. In other cases, new substrates have been developed, which required different ink formulations in order to achieve good ink film properties. It may be instructive to review some of these revolutionary inks, and look at what caused their development and the results in the marketplace.

Heatset Printing

The first development we will look at is the invention of heatset inks, which occurred in the 1930's. Most of the paste ink printing, both lithographic and letterpress, was done on sheetfed equipment, because of the drying mechanism of the inks used at that time. The prevalent ink formulations at that time dried mainly by oxidation, which took at least 6-12 hours. This prevented high speed production of prints and precluded printing on a web. Heatset inks, however, did not dry by oxidation but by a combination of evaporation and penetration. They contained 40-50 percent of a blend of petroleum hydrocarbon fractions, which had a very narrow boiling range, and most of them were similar in volatility to kerosene. In addition, hard resins were used in place of drying oils as binders in these new inks, thus producing a hard film after the majority of the solvent present was evaporated.

Drying equipment and web presses for letterpress printing were developed to allow printing at speeds of 700 feet per minute. The first drying equipment that was developed was similar in operation to the dryer "cans" used in papermaking machines. It consisted of a large metal drum filled with steam, over which the web was wrapped. While this steam drum dryer worked fairly well, it did not permit speeds to increase much, due to the need to transfer heat through the paper before it could reach the ink film and limited temperatures. Later on, direct flame dryers, which impinge open gas flames directly on the top of the web, were developed. These dryers allowed an increase in speed of the web and in addition, helped to burn some of the evaporated petroleum solvent. However, they were dangerous when a press stop or a web break occurred, because the flames could start a fire if they weren't shut off quickly enough, even though valved to the press speed controls. Other types of ovens were designed using radiant gas cups and after that those using high velocity hot air nozzles. The HVHA are the type of ovens used in modern high speed printing.

Steamset Inks

In the 1940's a new type of ink and drying system was developed,where high pressure superheated steam was blown on the web, causing setting and eventual drying of the ink film. The operating principle of this ink was absorption of water vapor from the steam by ink containing a solution of resins in glycol solvents. These resins became insoluble in the glycol when it contained enough water. At this point, the resins would precipitate and bind the pigment to the substrate, which would absorb the solvents.

The superheated steam was created by passing saturated steam through perforated pipes containing internal electric heaters to assure that the steam had no condensed water, which could break the web. These inks were widely used for printing low odor products, like napkins and paper bread bags, waxed after printing.

Some of the problems with steamset inks were low gloss and the fact that the ink film was set, but not completely dry off the press.

Web Offset Inks

In the 1950's lithographic offset presses, which had been mainly sheetfed for many decades, were redesigned using a continuous web in order to achieve higher printing speeds. This necessitated the development of completely different lithographic ink formulations. The conventional sheetfed litho inks were formulated to dry by oxidation or setting plus oxidation. These inks could not be dried in the few seconds available for drying on a web fed press. Inks containing solvents similar to those used in the heatset letterpress process had to be formulated, but with the restriction that they also needed to achieve a good ink/water balance. New synthetic resins had to be developed which had the property of resisting the fountain solution and maintaining good rheology of the emulsified ink. In addition web inks had to be lower in tack and viscosity than sheetfed inks, otherwise paper surface problems such as picking could occur. This also tended to make the water balance narrower.

Flexographic Film Inks

In the early 1960's flexo inks were developed that could successfully print and adhere to the new polyethylene films that had become available for packaging markets. These inks were based on resin chemistry similar to that used in the manufacture of Nylon. That is they were polyamide type resins, but modified chemically so that they were soluble in combinations of alcohol and hydrocarbons. Previous inks for printing flexo on polyethylene film were formulated using shellac, which had become quite expensive and was in limited supply. With these new inks available, the use of film to make bread bags, which is a huge market, took over from waxed paper bags in less than two years; and polyamide flexo inks quickly became the standard in this packaging area.

Energy Curing Inks

In the late 1960's ultraviolet (UV) and electron beam (EB) inks were invented. These inks were quite revolutionary in that they contained no solvent and no resin but still dried or "cured" instantly upon exposure to UV or EB energy, respectively. The inks also were infinitely stable until exposed to the appropriate energies and thus could be left on press for extended periods of time. The instant cure feature allowed in-line processing and diecutting to be done thus producing a finished package.

The UV inks were formulated with monomers and prepolymers of unsaturated chemicals and contained a photoinitiator instead of a drier. The photoinitiator when subjected to UV light would dissociate and cause the reaction to occur instantly, producing a solid polymer within the ink film. The EB inks required no initiator due to the higher energy of the electron beam.

The equipment to safely cure these inks on press had to be developed, as well as new elastomeric materials for rollers and blankets, since the old rubber materials would be strongly attacked by these new formulations. Procedures for handling these inks to avoid skin and eye irritation had to be developed and slower curing with black, white, and metallic inks also required reformulation.

High Speed Lithographic Inks

In the early 1980's litho press operating speeds started a sharp increase which, during the decade, more than doubled to 2,000 ft/min (10 m/s). These new higher speed presses challenged ink formulators because both tack and rheology needed to be lowered to accommodate the high web speeds without damaging the paper surfaces. This put further stress on the rate and type of emulsification behavior that the ink would exhibit with fountain solution. New types of binder resins had to be developed so that proper emulsification would occur very quickly. Another consideration was that the drying of the web at these higher speeds required more oven length; and some of the adjustment techniques used to enhance HVHA drying in the past did not seem to increase the efficiency of the dryer as well as they seemed to in the past. It was subsequently found that the limiting factor on drying was not air flow or temperature but the rate of diffusion of the heatset solvents through the partially dried ink films. Studies conducted showed that a typical four color ink film would require about one second residence time in the dryer, thus dictating the dryer length required for a given operating speed.

Present Trends – This Decade

During the 1990's four factors have put considerable pressure on ink formulation and printers in general. These are:

1. increasing regulatory pressures
2. increasing local geographic and global competition
3. increasing competition from other communication media
4. increasing demands for improved production efficiency and consistent quality of printing.

There remain many challenges to litho ink technology at present even though press speeds are now approaching 3,000 ft/min (15 m/s). The particular situations that need attention by ink chemists are controlled dot gain and good uniformity of printed solids, which generally conflict with one another. Another area of concern is the control of misting which is exponentially worse as speed increases. Wider water tolerance is also desired since this leads to lower waste, quicker make-ready, and higher production efficiency for the printer. Of course, anything that improves drying rate will help to minimize the increased length and cost of the mechanical heatset drying equipment.

In the packaging area, flexo water based ink technology has grown greatly but there remain some problems that prevent its further penetration of this growing market. The increased use of four color process printing on flexo printed packages demands a better rheological control of the formulation, which should result in better control of dot gain and good color reproduction. Increasing drying rates and improving the wetting of and adhesion to the wide spectrum of packaging substrates is also an important goal. However, the discovery of new and innovative vehicle chemistry is the most likely thing that can produce substantial improvement in all of these properties.

Despite the growth of energy curing UV and EB ink technology since its inception, there remain important hurdles to overcome in order to capture more markets. One important consideration is the reduction and/or elimination of low molecular weight monomers. These can be a source of residual odors in the cured prints and may sometimes be the basis of skin or eye irritation. Another formulation parameter that is needed is controlled oligomer and vehicle rheology. Since solvents cannot be used to adjust the ink body, the formulator needs the flexibility of controlling the ink viscosity, either to increase or decrease it depending on the printing method, by choice of the proper vehicle raw materials. The third area that needs further work is the development of new reactive chemical species to improve both properties and most importantly economics. The relatively high costs of UV/EB materials is a definite limiting factor in their penetration of certain markets.

Printing Ink Technology in the New Millennium

An attempt will be made to predict which significant changes may take place during the next ten years in the major types of printing ink technology. Since lithography will undoubtedly still be the dominant process we will start with it and continue with gravure, flexography, screen process, and finally, digital printing.

Lithographic Ink Technology

It is expected that the conventional type of two fluid lithographic printing will continue to dominate this market because the large installed equipment base and the economics of the process will help to slow penetration of other technologies. Some erosion of the market will occur as waterless litho printing and other new single fluid technologies are introduced and grow. The waterless area is a true single fluid process, since there is no fountain solution. It will grow in use as the supply of waterless plates and competition between plate vendors increases as existing patents expire. Also new types of ink chemistry will be developed and press cooling systems will become commonplace on new press equipment. These factors will improve the process efficiency and economics and increase the market share of this process.

Self dampening litho ink (also called "single fluid") is a preformed emulsion of fountain solution in the ink. The growth of this type of ink technology depends on the availability of special inking systems, such as keyless types, and therefore may be limited to new press equipment or those that can be economically retrofit. Coldset ink on uncoated paper is probably the first candidate for the use of self dampening ink technology.

Publication Gravure

Solvent based publication gravure with solvent recovery will continue as the dominant process, as long as environmental regulations permit the widespread use of toluene. It is the most economic process and well established in both printing and ink technology. If regulatory laws should be changed or more strongly enforced, two contenders are likely to be considered as replacements for the existing hydrocarbon solvent inks.

One is water based inks which have been extensively trialed in the past and present. Economic considerations still remain the principal limiting factor, due to slower drying rates, paper interactions, ink cost and any possible press modifications required. There may be penetration of some geographic markets by water based inks, where the absence of solvent odor and residual toluene is necessary.

The second contender is phase-change ink. These inks are being actively researched at present but require considerable change to the printing equipment to allow it to run at elevated temperatures. This factor may limit the use of this type of ink to new equipment. In addition, the formulation of hot melt inks to obtain proper rheology for good printing and still produce good functional ink film properties with reasonable economics, remains a challenge.

Packaging Gravure

The use of water based inks in packaging gravure will exceed fifty percent of the market, even excluding the gift wrap segment, which is presently almost 100% water based. Since some of the more complex solvent based inks will be still used due to substrate adhesion and functional ink film requirements, the use of solvent recovery and incineration as control methods will probably both remain in use.

Flexography – Publication

The use of water based flexo to replace letterpress newspaper printing equipment should increase somewhat, but the large installed base of litho presses will limit strong growth in the coldset printing market.

Flexography – Packaging

Flexo printing should increase its market share in the packaging business due to the greatly increased quality of four color process printing now being done, as well as good overall economics. The present high percentage of water based flexo printing will continue to increase due to regulatory pressures and improved vehicle chemistry.

The penetration of UV flexo inks will continue to grow in the narrow web and label printing markets. Commitments by wide web printers to UV are likely to remain limited to certain markets. The use of water reducible UV flexo inks will also be more widespread, since they help to lower viscosity and improve economics.

Screen Process Printing

The screen printing market will continue to grow because of the specialized nature of the inks that can be used in this unique process. The thick ink films and adaptable press equipment allow the quick utilization of new ink chemistry which provide further markets for the growth of this process. UV inks, both water reducible and 100% solids, will show good growth in screen printing, especially where film properties are important.

Digital Printing

Electrographic printing processes continue to claim a large share of the short run, plateless color printing market. The Indigo, Xeikon, Docucolor, Spontane, and various color copiers are examples of equipment that will be widely used for electrographic printing using "toner" types of ink. Both liquid and powder types of toners should grow and the availability of these products from mainstream ink companies should increase.

Inkjet printing will continue to grow strongly as an output device for computers. Wide format multicolor jet printing equipment as well as jet proofing equipment will also continue to grow and provide expanding markets for water based jet inks, both pigmented and dye types.

Other digital processes such as thermal transfer, sublimation, and other new processes will also be vying for a share of the imaging techniques that can be used for digital printing. These are likely to occupy a smaller part of the market for digital inks.

Conclusions

As other innovative digital imaging technologies evolve and take their place in the market place, inks with the required properties for operation in these new systems will need to be developed as they will be an integral part of the total printing system. Equipment manufacturers will undoubtedly find it expeditious to partner with ink manufacturers in accomplishing the most efficient development of new imaging equipment.

A Goal

The ink manufacturer, who is constantly searching for new types of inks as well as better ways to accomplish imaging, should have a goal for future ink development. A succinct statement of this goal might be as follows:

To create a single phase fluid (liquid, powder, or vapor) that can be instantly converted to form a stable image on a suitable substrate, preferably with the use of little or no external energy, and to emit no toxic byproducts.