CHAPTER II

THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1 Theoretical background

2.1.1 Basics of flexography (1)

Flexo is related to letterpress in that it also prints from a raised image. Its printing plates are generally made of flexible, elastomeric materials. The area of the plate carrying the ink is the raised portion obtained by removing and lowering the nonprinting areas through cutting, molding, etching, dissolving or washing them away.

Flexo inks are traditionally thin highly fluid and rapid-drying, although a trend toward paste-type inks is increasing. They are formulated from resins which are both solvent and water reducible.

Plate materials include various moldable, natural and synthetic rubber compounds and photopolymer materials. Plates are generally affixed to a plate cylinder with double-sided sticky tape supplied in widths up to 18 inches wide.

Press frame designs include central impression, inline and stack types. The central impression uses one common impression cylinder around which two to seven printing stations are placed. The inline design involves a tandem series of printing stations placed in a row. The stack version involves individual printing stations mounted on frames one above the other in two “stacks” generally one to four on each side of a vertical frame.

The typical flexo printing station or roller grouping from ink reservoir to substrate impression cylinder generally includes four rollers. A rubber roll turning in ink delivers ink to a steel or ceramic inking roll, a plate cylinder and the impression cylinder figure 2-1.

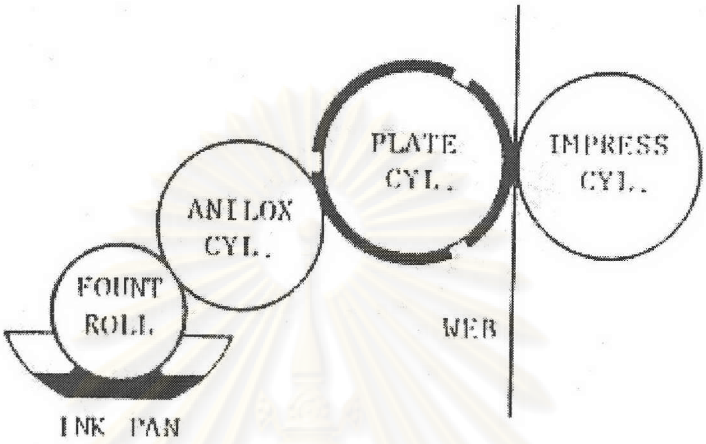

Figure 2-1 Flexographic printing station.

Flexography is unique other printing processes in that it was developed primarily for the printing of packaging materials. Since packaging materials are mostly used in roll from for feeding into from and fill, overwrapping, bag making and other continuous web processing machines, it follow that most flexographic printing is done roll to roll.

2.1.2 Photopolymer plate

The direct photopolymer plat is one of the major innovations in modern flexographic printing. It affords the ability to transfer an image from a photographic negative directly onto the surface of the printing plate, thereby giving excellent image fidelity.

Photopolymers are ultraviolet light sensitive materials and are used to prepare printing plates for flexography, letterpress and offset, as well as printing resists and proofing films. Flexographic photopolymer printing plates are similar to molded-rubber plates in that both are flexible, resilient and have excellent ink transfer. There are many systems available for producing photopolymer flexo plates

Raw materials are available as either viscous liquids, ready to be cast to a desired thickness, or as preformed solid sheets of an appropriate thickness. Photopolymer materials, whether liquid or sheet, are converted to flexographic printing plates when exposed to ultraviolet light passed through a photographic negative image of the artwork to be reproduced. The photopolymer is then processed to develop the relief image figure 2-2.

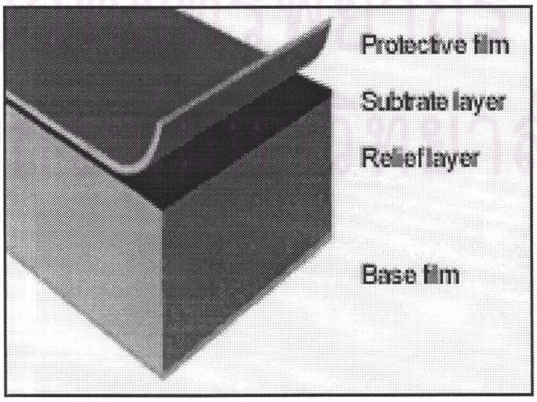

Figure 2-2 Structure of a monolayer flexographic plate.

2.1.3 Plate system (2)

Photopolymer plates are expected to produce good area coverage with low dot gain , fine reverses and light halftones. In corrugated post printing, the system used may often differ in the type of the potopolymer plate employed, the cushion material used and the double-sided tape applied. The choice of the particular elements used have an impact on the plate's performance, the dot gain and ink release, the extent of dot gain is dependent on the type and caliper of plate, the pressure absorbency characteristics of the cushion and the press settings chosen.

2.1.4 Defining new quality standards in flexo printing (3)

Flexographic plate making can be a complex process in which the differing needs of the end-user . Photopolymer plate consist of four main constituents binders, monomers, photo-initiators and additives and properties combination and interaction of these components play a crucial part in print performance.

In practice printers have used different photopolymer printing plates in combination with different tape, cushion backing and sleeves. This has been done to make maximum advantage of plate characteristics such as elasticity , durometer and ink transfer capabilities in order to suit a specific application or a certain substrate. The most common demand is for plate to produce and even and dense ink transfer, with 10 percent dot gain. Other frequent requirements are for accurate and clean print-out of fine reverse and line elements, the elimination of filling-in and smooth printing of difficult tone gradation (60 l/cm – 150 lpi with conventional halftone screens). The plate is required to be suitable for all ink sysytem, not only for water-based and solvent-based ink system, but also for test UV curing inks. In hardness term it should exceed 60 ShA (ISO) so as to reduce dot gain characteristics, but at the same time printers are looking for high elasticity for ease of mounting and to reduce make ready times.

As recognized throughout the industry, one of the unfortunately characteristics of flexography is that print pressure is always set higher than theoretically required in order to achieve an even ink transfer. This is done to overcome inconsistencies in plate thickness, mounting press, sleeve and surface structure of the substrate in use. The pressure is partially absorbed in the printing plate, which can lead to differing levels of dot deformation.

A highly uniform print-out is achieved even when using the entire printing which with different pieces of plate of the same thickness.

2.1.5 The compressible tape system (4)

The photopolymer plate is attached either directly to the steel cylinder by means of foam adhesive tape or to the hard sleeve. Care should be taken to match the tape's adhesive properties to the surface to be glued and it's compressibility to the imprint. For pure harftone printing, a softer undercut should be use to avoid increased dot gain due to deformation of haftone dots, ie a softer foam adhesive tape for combination halftone and line work on a plate, on the other hand, a harder foam tape should be use adhesive the necessary solid density.

The structure of a soft, foam-coated sleeve provides the compressible sub-structure desired. Such sleeve are mostly equipped which upper layer made of compressible material. The sleeve's compressibility must match that of the print. In this system, the printing plate is fixed to the sleeve using a non-compressible film tape. The tape adhesive properties should be matched to the surface of the sleeve and the back of the photopolymer plate. Tape most suitable for this application usually have sizes with widely varying adhesive powers.

2.1.6 Print evaluation (5)

The opportunity for evaluation period to compare plate with various print in the paper .

A number of check-procedures were introduced to achieve a stable print quality

1. Checking the technical condition of the press such as register, balance of anilox roller, doctor blade systems, doctor roll systems ect .
2. Checking the plate quality such as reproduction properties, thick-ness tolerances, ink transfer properties,dot gain characteristics,clean printout etc.
3. Checking reference values such as process printing, mount-ing,storage ect.

Checking press settings and material specification: plate system, cushion, ink , paper quality.

The establishing of standard procedures is recommended for producing a high quality printing result.

- Determine the colour sequence e.g. four colour (CMYK), three colour (CMY), colour switch: (darkest colour first, lightest colour last).
- Fill the ink duct. Determine the ink quantity being transferred. Determine viscosity, pH value and temperature.
- Set the minimum pressure necessary between plate and impression cylinder.

- Set the register carefully.
- Optimise grey balance.
- Set high and low print speeds, run several sheets and determine accurate register.
- Evaluate the printing result and supply data to your pre-press partner

2.1.7 Material preparation

Unexposed plate material should be cut carefully to minimize waste. Typically, on a sheet of raw photopolymer, there is a small border of cured material around the edges of the sheet.

The film negative size is transfer to the plate material, which is then placed face-up on the sheet-cutter board. Smooth, clean cuts should be made either with a sharp knife or a “hot knife”, allowing a l” border around the copy to provide a clamping edge.

It is more practical if several negatives can be grouped together to from a single sheet exposure, thus eliminating the necessity to cut individual sheets of raw material. When grouping negatives do not over lab. UV-opaque adhesive tape should be use to eliminate gaps and to ensure that the negatives are kept flat

2.1.7.1 Back exposure

The back exposure is completed first. The sheet material is placed base-side up on the exposure unit and exposed to UV light. Some automated systems are equipped with dual light sources. In that case, the sheet is placed base-side-down over the bottom set of lamps. The back exposure is responsible for the polyester backing sheet, and presensitizing the material for shorter main exposure times. Negatives are not used during back exposure. The exact back-exposure times are determined using back-exposure step-test procedure.

2.1.7.2 Main exposure

The plate material is turned over and the coversheet is removed. Clean negatives are placed emulsion down on the material and the vacuum sheet is smoothed over the material. In systems equipped with dual light sources, the plate material does not need to be turned and this step is combined with the back-exposure step. The UV lights are then turned on for a specified amount of time. When the plate material is exposed through the negative with UV light, the areas corresponding to clear areas on the photographic negative are hardened. The areas, corresponding to the back areas in the negative remain unexposed (uncured)

2.1.7.3 Face-test exposure

Face-test exposure should be conducted to determine the exposure necessary to reproduce the copy detail. Image-stepped test negatives containing a variety of copy detail and tonal valued are available from various suppliers. Once the desired back exposure is established, these images are face exposed for various periods to establish the time necessary for plate production.

2.1.7.4 Plate processing

After exposure, the plate is ready to be processed in the washout unit. This unit removes uncured photopolymer material leaving the cured image in relief. A processing solution together with a brushing action removes the uncured material, which then dissolves in the solution. Washout conditions may vary considerably from one manufacturer's system to another. Most plate material suppliers also supply an alternative, more environmentally friendly, line of solvents than those marketed in the past. Plate processing units come in both rotary and inline versions. Some important considerations in processing are brush pressure and replenishment of solvent chemistry. Typically, shot washout time can cause shallow relief, tacky and uneven background (floor), and surface scum (dried polymer on image surface). Long washout time can cause damaged or missing characters, excessive swelling and uneven plates. The appropriate conclusion for best processing time was polymer processing manual.

2.1.8 UV Flexo Ink (6)

Ultraviolet flexographic ink differ significantly in composition from solvent-based ink. Most ink contain pigments and special additives, but what separates UV ink from conventional sovent-based or water-based ink is the use of oligomers, monomers and photoinitiators. The oligomer is the resin, or vehicle, of the UV ink. The functional properties are dictated by the choice of oligomers and monomers.

Unlike conventional ink, the press properties of UV inks are not sacrificed by attempting to achieve superior end use or performance characteristics. This is due to the ink's capacity for intermolecular bonding or crosslinking. Another unique trait of UV inks is that their superior functional properties can be modified by the addition of monomers. Monomers, link solvents in conventional link, are used to adjust the viscosity of an ink Unlike their solvent counterparts, monomers do not evaporate, but rather crosslink and become part of the cured ink film.

Photoinitiators are molecules that absorb UV energy and then use that energy to initiate a polymer chain reaction. The two most common photochemical mechanisms use in UV flexo inks are free radical and cationic. They each have their advantages and disadvantages, so it is important to look into both chemistries when choosing a UV ink

After the ink is printed on the substrate, it is passed under a source of UV energy, typically a UV-curing system. The UV-curing system is composed of a UV lamp, a reflector, a power supply and a control unit. The lamp is a transparent quartz tube filled with an inert gas, typically argon and a small amount of mercury. Quartz is use because it is transparent to UV, whereas normal glass is not. Mercury is used because of its strong emissions in the ultraviolet range. The systems are rated in watts per linear inch. Newer systems are normally 400-600 watts per linear inch. The reflectors for UV-curing units typically employ the energy delivered to the chemistry. This focused UV energy is then absorbed by the photoinitiators. The photoinitiators transform into free radicals for the acrylate chemistry or Bronsted acids for the cationic chemistry. (7)

Free-radical and cationic ink utilize a chemically different set of oligomers and monomers, so the end properties are also affected. Free-radical acrylate-modified epoxies, urethanes, polyesters and other materials. Coinitiators are added to prevent oxygen inhibition of the free-redical curing. Cationic chemistry is based on epoxies, which crosslink when reaction to acids. The initiator in cationic curing is a blockedacid catalyst which is released by UV energy. There are advantages and disadvantages to each chemistry.

2.1.9 Contact Angle

General definition of classification of contact angle has been studied for almost 200 year since the publication by Young. **(8)** Contact angle is the angle obtained between a surface substrate and a liquid droplet. The well known Young equation **(9)** was developed for an ideal solid surface, namely a perfectly smooth, chemically homogeneous rigid, insoluble and non-reactive surface. The contact angle on such a solid surface is called the "intrinsic contact angle". Most real solid surfaces are rough and chemically heterogeneous. For such surfaces, the contact angle may change from one point to another along the contact line. The angle between the direction of the tangent to the solid surface at a given point and the direction of the tangent to the liquid-fluid interface at point is called "smooth" solid surface, as seen by using relatively low magnifications, and the direction of the tangent to the liquid-fluid interface is called "the apparent contact angle".

2.1.10 Film Splitting Machanism

Banks and Mill **(10)** described the process of repetitive ink film splitting at the exit of a nip formed by two cylinders. They considered a four-step sequence : (1) cavitation , (2) filament formation , (3) elongation , and (4) rupture. In printing nips, fresh ink comes into contact with an unlinked paper surface, and splits only once. However, it has been assumed that the same four-step process is also in operation under printing condition .

The printcipal parameters involved in the splitting process are found in the Appendix. The interrelationship between these parameters and the behaviour of inks during splitting may be understood by observing the formation and the evolution of a filament of ink attached to the surfaces of the two cylinders forming the nip as shown in Fig 2. Only one of several cavitation bubbles and filaments across the nip are shown for clarity.

Stage I

At the nip center, the distance, h, between the two cylinder surfaces at the nip center is equal to the thickness of the ink film in the nip (X), The cylinders rotate at a tangential velocity (V). As the ink emerges at the nip exit, the surfaces of the cylinders recede from each other. The separation velocity (Vs) and a tensile force is applied to the ink film. The tensile stress is relieved by cavitation within the ink film (group 1). At this point, the pressure in the ink decreases suddenly.

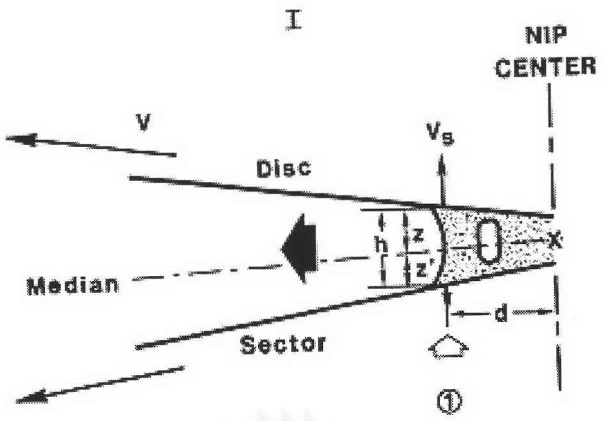

Figure 2-3 The development and rupture of ink filaments during splitting of ink films. As the ink film (X) emerges from the printing nip (I), the distance from the nip center (d), and so h and Vs, increase from the onset of cavitation, at the nip exit, through the formation and elongation of filaments (II,III) , until the ink film splits through the rupture of the filaments(h_r,d_r,V_{st})(IV,V).

Stage II

As they are carried further away from the nip, the surfaces of the cylinders continue to separate and the cavities (group 1) expand vertically. Filaments of ink are formed between the cavities as the cavitation bubbles open to the atmosphere. Subsequent cavities an filaments are formed as long as ink continues to emerge from the nip (group 2,3, etc.).

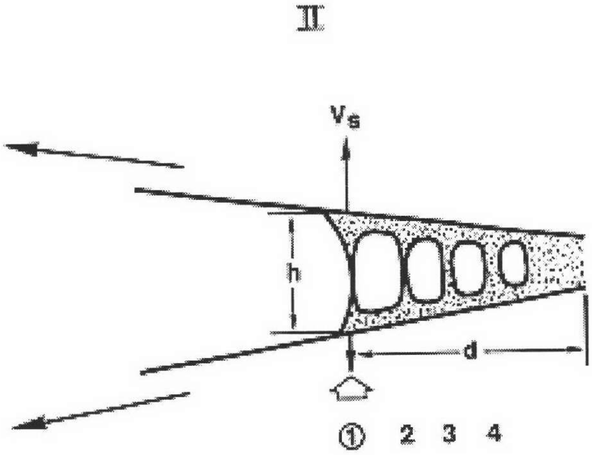

Figure 2-3 (contd.)

Stage III

The filaments (group 1) elongate and become thinner as they continue their travel away from the nip. The rate at which the filaments elongate is equal to the rate at which V, increases. This is referred to as the filament acceleration.

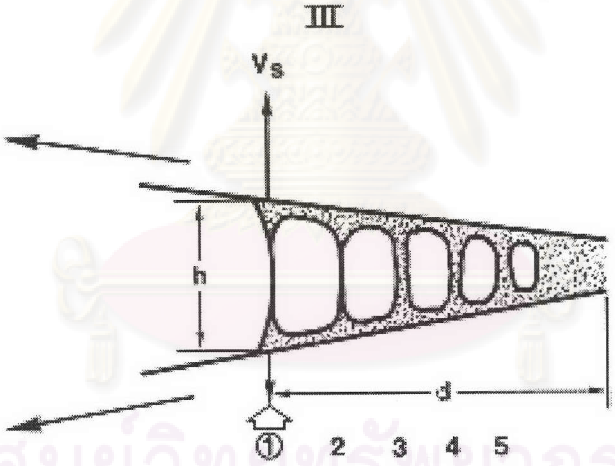

Figure 2-3 (contd.)

Stage IV

The ink film splits as the filaments (group 1) rupture, probably through tensile failure. The length of the filaments at rupture, hr , may be considered to be a measure of the 'shortness' of an ink. Ink shortness has been related to misting and picking during printing.

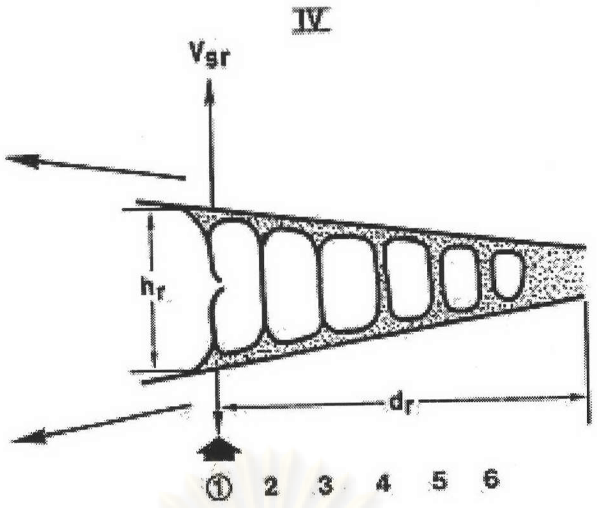

Figure 2-3 (contd.)

Stage V

The ruptured filament segments (group 1) recoil toward the cylinder surfaces. In printing nips, the splitting process continues (groups 2, etc) until all of the ink on the image area on the printing form has passed through the nip.

At commercial printing speeds, the time elapsed from the moment the ink film on the printing form enters the printing nip to the splitting of the film at the exit, is in the order of about a millisecond. At a printing speed of 2.6 m/s, the filament acceleration in the IGT press is 308 m./s^2. Taking into consideration the differences in the radii of the print cylinders, the same filament acceleration is found in found in a commercial press running at 45,000 copies/hour.

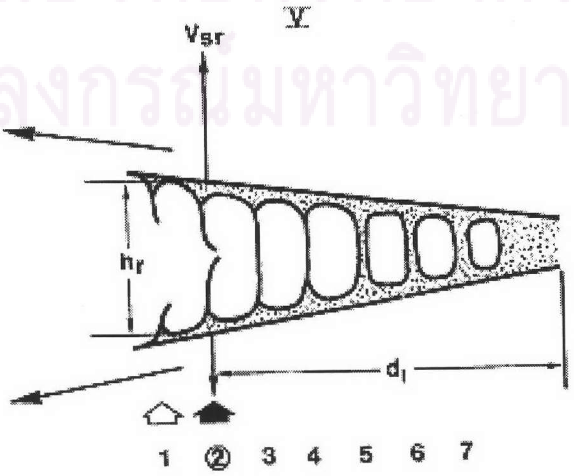

Figure 2-3 (contd.)

2.2 Literature Review

Lagerstedt and Kolseth (11) concluded that the surface roughness exerted a greater influence on the ink transfer than the surface energetics even though this was not self-evidently valid at low tone values. The surface energy affected the ink transfer in the border zone between printed and non-printed areas through a poorer adhesion of the ink to the paper, which at low tone values gave rise to visible effects

De grace and Margin (12) investigated the effect of substrate properties and condition on ink transfer. He found that a substrate permits significantly greater amounts of ink to be hydraulically impressed during printing than does a non-porous substrate at the same level of roughness. It is also found that printing pressure has little effect on the transfer of ink to relatively smooth polymer films but transfer to roughened polymer films and to newsprints increases when pressure is increased

Lindholm and Ström (13) The idea was to use infra-red technology (IR) to detect the amount of ink. Since water-based flexographic inks were used, the instrument was expected to respond to the amount of water and it was conceived that the amount of ink could be determined on the basis of an initial calibration. The measurements were made through a narrow band filter, at a wavelength of 1.94 μm where the IR absorption by water is highest. The IR camera measured continuously on the moving anilox roller, on the plate or on the web. The amplification of the signal was adjusted to cover the span between the lowest and the highest measurements. The response time of the device was adjusted to yield a useful signal without too much disturbance.