CHAPTER 2

THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1 Theoretical background

2.1.1 Principle of flexographic printing[2]

Flexographic printing is a direct relief printing process. It differs from conventional relief printing in the printing plate and printing ink used as well as in the ink transfer process itself. Printing is carried out primarily on a rotary basis, i.e. the printing substrate is processed in reels. Sheetfed printing machines are only used in the direct printing of corrugated board.

During printing, printing ink is transferred through four main components: an inking unit, an anilox roller, a photopolymer plate and finally to the printing substrate.

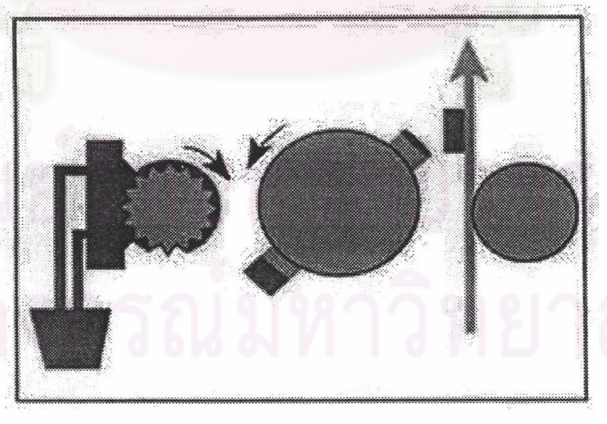

Figure 2-1 Diagram shows the rollers in the flexographic printing unit

2.1.2 Photopolymer plate

The printing plate is the first of the special features of flexo printing that should be mentioned. While rigid printing plates made of metal or plastic are required in conventional letterpress printing, elastic printing plates are used in flexo printing. These elastic printing plates react sensitively to any pressure that is applied to them, with the result that the printing relief is deformed.

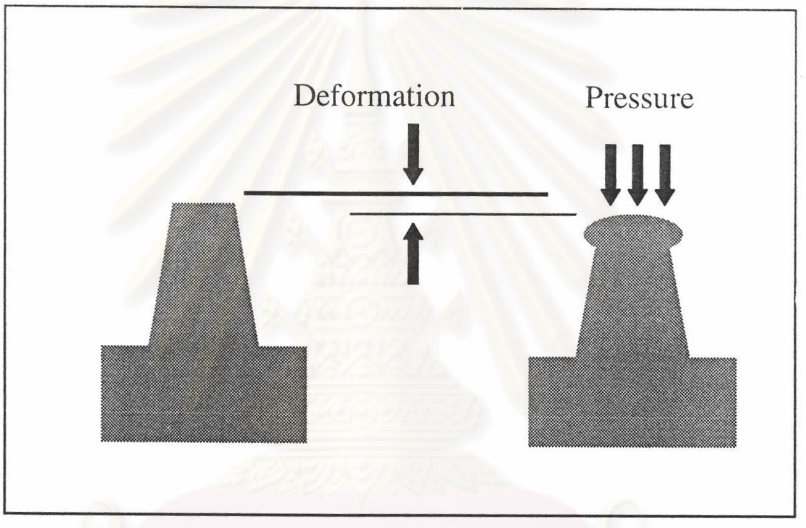

Figure 2-2 Deformation of the plate due to printing impression

A certain amount of pressure is needed in every printing process to transfer ink from the printing plate to the printing substrate. Where as pressure is applied to the whole of the surface in offset and gravure printing and this pressure can be relatively high, pressure is only exerted on the printing elements themselves in letterpress printing due to the raised printing relief. The pressure level required in the printing process has to be adapted to the motif and the printing substrate in accordance with its surface roughness. The general principles of printing pressure can be summarized as follows:

The finer the printing elements, the lower the pressure that is required.

The rougher the surface of the printing substrate, the higher the printing pressure.

2.1.3 Making of photopolymer plate[3]

Steps for making sheet photopolymer plates follows.

Material Preparation

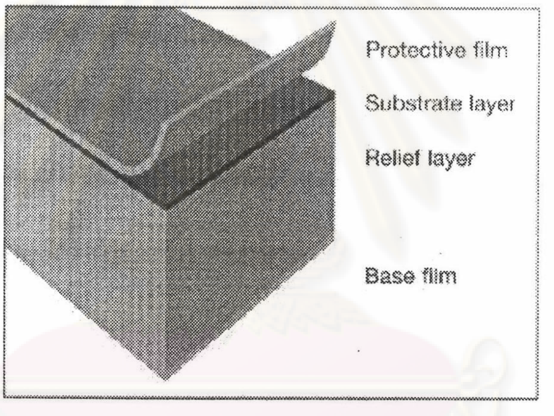

Figure 2-3 Structure of a monolayer flexo plate

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 transferred 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 1" border around the copy to provide a clamping edge.

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

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 relief depth and floor thickness of the finished plate, increasing adherence to 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 a back-exposure step-test procedure.

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).

Face-test Exposures

Face-test exposures should be conducted to determine the exposures 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 times necessary for plate production.

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, short 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. Consult the appropriate polymer processing manuals for the best processing times.

Preliminary Inspection

After a belief time in the dryer, the plates should be inspected and wiped to remove the thin film of residue that may remain on the print surface of the plate. Failure to remove this film will result in the appearance of "orange peel" or dry-down spots, which may appear principally on solid areas and around reverses. The plate should also be checked for correct processing and floor formation. A poorly processed plate may be reclaimed by reprocessing at the correct settings.

Plate Drying

When solid-sheet plates are removed from the washout unit, they are soft, swollen and tacky. Processing solvent is absorbed into the plate during washout, causing the plate to swell. As a result, straight lines become wavy and type is distorted. Oven drying will evaporate this absorbed solvent. The plate's swelling will reduce, making the images sharp and clean. A fully dried plate will return to the original gauge of the material.

Time and temperature must be controlled for proper plate drying. Plates not dried sufficiently may be swollen and uneven in gauge. If the drying temperature exceeds 140° F (60° C), the polyester backing may shrink and cause the plate's dimension to change. Process-color plates generally take longer to dry than line plates. Follow the plate material and equipment supplier's recommendations for setting dryer temperatures and times.

Plates will still be tacky when removed from the dryer, and care must be taken not to touch the surface of the plates because fingerprints will be left on the finished plate. After drying is complete, the plate back should be wiped with clean solvent and a lint-free wipe to remove any polymer residue prior to light finishing.

2.1.4 UV Flexo Ink[4,5]

Unlike conventional water-based or solvent-based flexographic inks and coatings, UV-curable products do not dry through evaporation and absorption of solvents. Instead, they are converted, or cured, to a dry solid state through a chemical process called polymerization. This cycle begins when the ink or coating is exposed to ultraviolet light of sufficient energy to initiate the following chemical reaction. Upon exposure to the ultraviolet light, the photoinitiators contained within UV inks and coatings are transformed into free radicals. Free radicals are simply groups of atoms with an excess of electrons. These extra electrons want to pair with something, in this case with the oligomers and monomers of the ink or coating. The oligomers and monomers simply become chained together, binding the pigments and other additives in the polymer chain. In the case of the less commonly used cationic chemistry, the photoinitiators are converted into acids that act as catalysts to cross-link an epoxy system. Free radical or cationic, whatever the case, all of the elements of the UV-curable product become tightly bonded into a polymer through cross-linking.

After this bonding occurs the UV ink or coating is then inherently stable. Since there are no solvent to evaporate, color consistency and print sharpness are increased. Other related advantages include:

- Greater uniformity in coating weights;
- Reduced “fill in” of type and reverses;

- Reduced dot bridging in screens;
- Plates and fountains require less cleaning than those used with conventional inks or coatings;
- Heavier ink deposits and greater opacity are possible, since none of the ink components are lost in the curing process; and
- Once cured, the ink or coating becomes tightly cross-linked – a plastic-like solid with a more uniform surface, higher gloss, and excellent scuff -, abrasion- and chemical-resistance properties.

Apart from the print quality issue, a concern in health and safety is another important thing that spreads out the use of UV ink. A major concern with conventional chemistry is the fact that these formulations contain chemicals that are volatile. Volatile chemicals may release vapors that can then be inhaled by workers. Typical UV formulations do not contain solvents and do not contain VOCs. This eliminates the considerable health risks associated with vapor inhalation. Table 1 compares the toxicity of several typical UV curing materials and several solvents. TMPTA is trimethyol propane tri-acrylate, a common monomer used in many UV and electron-beam curing materials. The oligomers used in UV and EB products are much higher in molecular weight so the properties for the categories listed in the table are the same for most oligomers.

Table 2-1 A comparison of the toxicity and other properties of UV-curable ink component and some commonly used ink solvents

Chemical	Flash Pt.	VOC	Hazardous waste	Systemic Skin Irritant	Toxicity	Reproductive Effects
TMPTA	>212 °F	No	No	Yes	No	No
Oligemer	>>212 °F	No	No	Maybe	No	No
VM&P Naphtha	<0 °F	Yes	Yes	Yes	Yes	No
Toluene	40 °F	Yes	Yes	Yes	Yes	Yes
Xylene	100 °F	Yes	Yes	Yes	Yes	Yes
1-Butanol	100 °F	Yes	Yes	Yes	Yes	Yes
2-Butoxyethyl Acetate	190 °F	Yes	Yes	Yes	Yes	No

In other areas of safety relative to the environment, UV chemistry is superior compared to conventional solvent- and water-based technologies. In addition to the volatility (VOC) issue, UV materials typically do not contain any compounds which must be reported under section 313 of the Superfund Amendments and Reauthorization Act (SARA), and do not contain any materials that are classified as hazardous air pollutants (HAPs). As long as the UV materials are not contaminated, they are not usually regarded as hazardous waste and unlike water-based materials, have an excellent BTU value for disposal as fuel. Table 2 summarizes some of these issues.

Table 2-2 Permitting requirements and pollution potential of UV, solvent-based and water-based ink

	UV	**Solvent**	**Water**
VOC	Nil	Yes	Yes
HMIS			
- Health	2-3	2-3	2-3
- Flammability	1	1-4	2-1
- Reactivity	1-2	1-4	2-1
SARA 313 Reportable	Not Usually	Maybe	Maybe
Calif. Prop 65	Maybe	Maybe	Maybe
HAPs Permitting	No	Permit Needed	Permit Needed
RCRA	Not Usually	Usually	Usually

2.2 Literature Reviews

Niederstad[6] studied the swelling behavior of nyloflex FAH and digiflex FAH DII plates against UV inks. The test was conducted under production conditions and allowing six hours run time in each case. It is found that there is a correlation in the time between ink temperature rise and dot gain, which could lead to the assumption that temperature also has an effect on plate swelling. It was also interesting to observe that the mechanical hardness of the plate deviated on average by only about 1° Shore A from the original hardness. Differences of up to 6° ShoreA which were found in static swelling tests were not confirmed.

Lagerstedt and Kolseth[7] 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.

Meyer and Leber[8] described the influence of printing plate on the reproduction of the printed image that depending on the type of printing plate, its mounting method and medium, certain type of printing result will be obtained. However the range of possible results overall is very wide. To enable print quality to be improved, standards need to be established for the printing plate, tape and mounting medium combination depending on the substrate and printing image being used.

Meyer et al.[9] explained that the printing plates had a direct influence on the quality of the printed image, depending on the printing material. It was also described that the choice of plate made no difference on film or very smooth paper with respect to print quality. This was not so with rough papers, where a 1.70 mm thick, somewhat compressible printing plate brought better results. The reason for this could be that, the 1.70 printing plate clings better to the rougher materials. This is noticeable both in printing results of the continuous tone and on the surface. The surface prints more in a closed manner, the screen definition is more regular. Unevenness in the paper surface can be compensated a little better with a softer printing plate.

De Grace[10] investigated the effect of substrate properties and press 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.