Process Color Pad Printing

by Peter Kiddell

As with most methods of reproducing process-color images, the creation of near-photographic quality separates the novices from the experts. Process-color pad printing has been practiced for many years and came of age when photographic images first saw use in CD printing, before the introduction of today's high-speed multipolar screen-printing presses.

At that time the output requirements were much less, with 500 discs/hr being acceptable. A pad-printed line ruling of 175 lines per inch allowed a tonal range of 5-95%, which was printed on a gloss white background, and the printed results were superb. Admittedly some of the designs were pretty wild, their designers having resorted to something stronger than Earl Grey tea before their creative sessions. But this was the pinnacle of multipolar pad printing and arguably the best quality direct CD printing ever achieved.

Why were these pad-printed CDs so good? Pad printing has characteristics that are ideally suited to high-precision process printing: thin ink films, very accurate registration, excellent dot reproduction, the ability to print fine line rulings, and no mesh-induced moiré. Although the current high-speed CD screen-printing machines exceed 4,000 images/hour, they are limited to coarser line rulings and experience inherent moiré problems associated with screen-printing.

Now that print buyers are so accustomed to photographic images and the design freedoms that accompany them, the demand for finer line counts and higher quality printing is greater than ever. It's a perfect time to think about process-color pad printing. And once again, the key to success is found reducing and controlling the variables.

Registration is one of the most important variables to control. It is affected primarily by the indexing accuracy of press's feed mechanism. Mechanical indexers should have positional accuracy of ±0.01 mm (±0.0005 in.). The jig must be stable and must hold the object firmly. (If you try to use a manually loaded single jig to print colors in succession you will find the process both time consuming and impractical.) The ink pick-up and print stroke of the pad requires similar accuracy. With these factors under control the foundation for good pad printing is in place.

The next decision involves the plate material. We recommend either a high-quality steel plate with a fine crystalline structure or a photopolymer plate. Personally we prefer the photopolymer plate because it generally enables you to use a finer line. But be aware that controlling the etch depth on photopolymer plates can be more of a challenge.

Regardless of the plate material the target etch depth is 20 microns. A steel plate will resolve a tonal range of 10-90% at 150 lines/inch while a photopolymer plate will resolve a tonal range of 5-95% at 175 lines/in. Dot shape is normally elliptical in pad-printed images, and halftone screens typically have the following angles: cyan, 67.50; magenta, 22.50; yellow, 90; black, 45. Stochastic screening also works very well on photopolymer plates.

The quality of etched steel plates would be better if many of their producers were better at controlling their production processes. Etch depth is often uncontrolled and definition is lost. For the vast majority of pad-printed images, the current offering of etched steel plates is more than adequate. But when your job calls for very small dots and line halftone work some suppliers are still struggling to produce an acceptable plate. Prepress is critical but you do not have the luxury of test strips and grayscales that other printing processes have. And there's the rub. Your inability to measure the image with a densitometer means that decisions about the quality of the image have to be made against a personal standard which amounts to a veer subjective assessment.
You have to be sure of the etch depth and ink condition. Dot reproduction with pad printing is very accurate and although there is some change in dot size, it is not as significant as in screen-printing. The change in dot size will be exaggerated if you over-pressure the pad. Consistent pad pressure on all the colors is critical. Pad condition also has to be monitored, as degradation of the pad surface will cause a color shift.

Ink condition is probably the most critical area of concern. It starts with the color as received from your supplier. You need to be assured that each ink and color has the characteristics you expect as specified by the manufacturer such as optical density. If you need to adjust the density, it’s always better to start with ink that has known density characteristics then simply reduce the ink with an appropriate amount of transparent base.

Your only method of increasing the density of a printed color is to increase your etch depth, and this is not a good idea! You are making decisions on color correctness without the aid of a densitometer, so adding yet another variable into the equation is an invitation for trouble. The solution is to purchase ink of a higher density than you require and reduce the density to the required level by adding base. This gives you a tool to modify color by altering only one parameter.

To obtain (and maintain) the desired transfer characteristics for the ink as you adjust its density, you will also need to measure the correct solvent mix into the ink. The density you decide to use for each individual color will be based on the values you establish when making separations. You have to replicate these densities in your print to get predictable results.

Successful process-color pad printing requires strict process control and a thorough understanding of printing technique. You shouldn’t consider process-color pad printing unless all of the following characteristics apply to your shop:

Your printing equipment is capable of holding tight registration.
You are currently able to control ink conditions on non-process color work.
You have written procedures for achieving accurate colors and consistently follow them.
If you wish to take on the challenge of process-color pad printing, congratulations! But before you proceed make sure you are aware of your customers’ expectations. Agree upon standards with the customer that you can maintain from the start of the contract until the job is finished. This will allow you to minimize the risk of creating a pile of rejects!

Digital Misprints
A customer once returned 20,000 printed plastic bottles to a manufacturer we known and all exhibited the same fault: The ink was not adhering properly in one specific part of every bottle. The bottle was a medicine container, printed in one color with very fine text. For obvious reasons, it was crucial that all of the instructional and dosage information remained on the container! The printer was also the bottle manufacturer and he was at his wits end trying to find out how to resolve the problem.

Upon visiting the facility it became clear that this company knew what it was doing. It had a well-organized production floor with top-end, properly maintained equipment. We looked first at the bottle presentment system, designed to improve ink adhesion to the material. The company used a flame-treatment unit with a controlled flame mounted inline on the press. It was in perfect working order and was ruled out as the culprit.

The ink was also not the source of the problem. The vast majority of the printed image passed the specified crosshatch tape test. The problem area was an oval shape, about 1 x ¾ inch large. It was time for some detective work.

We began exploring the process at the end of the printing line and worked backwards to the bottle-molding.
floor. Everything checked out, and everyone appeared to be wearing the correct personal protective equipment.

The bottles were blow molded, then exited from the machine down a ramp where an operator picked up the bottle and removed a small plastic burr with a sharp knife. He wore a glove on his left hand and held the knife in his right hand. The hot bottle was held in his gloved left hand while he cut off the burr. He then transferred the bottle to the right hand -between his thumb and the knife- to place it in the transport packaging.

The problem was his thumbprint. He was hot and perspiring, and the oils from his hand were contaminating the surface, prohibiting the flame treatment from improving the material's surface tension. The only way to remove this thumbprint was to use a solvent wipe. The solution was quite simple; he put a glove on each hand. This covered up the offending digit and the problem disappeared.

Regardless of the printing process you are using, handling the printing surface can wreak havoc on the print. Ink will only adhere if the surface energy of the substrate is higher than the surface tension of the ink -the ink has to wet the surface to be printed. With polypropylene and polyethylene, flaming, corona discharge, or plasma treatments are all suitable methods of making the surface wettable. They all increase the surface energy of the material to be printed -provided there is no skin oil or other contaminant on the surface.

Contamination by whatever means is a major problem for any surface. One of the most insidious contaminants is silicone spray, which is sometimes used for lubrication. The application of such a spray anywhere near surfaces that have to be printed or coated can disable a facility. So keep your operation printing profitably -keep it clean!

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Surface wetting
If the surface tension of an ink is greater than the surface energy of the substrate, the ink will bead up rather than flow properly. To make such a substrate wetable, and enable ink adhesion, substrate pretreatment is necessary. In order for an ink to adhere to a substrate, it must be capable of wetting the material. If this is to occur, the surface tension of the ink must be lower than the surface energy of the substrate.

Contamination in the form of oil, grease silicones, condensation, etc., will inhibit or stop ink from wetting the surface. Cleanliness is essential.

I can't overstate the need to accurately identify the substrate, as small changes in the chemical composition can radically affect the surface of the material. The most difficult situation is where surface conditions vary, either at different points on the substrate or throughout a production run. Plastics that are filled (e.g., glass-filled nylon, talc-filled polypropylene) of the filler rather than those of the plastic will change due to slip-additive migration. This is particularly so in applications where heat is applied to a molded component. Ink that appeared to have adequate adhesion can simply fall off when slip additives migrate to the surface.

Substrate pretreatment
The term polyolefins refers to a wide range of plastics. Some, such as polystyrene and vinyl, are very suitable for printing. Others, such as polyethylene and polypropylene, can’t be printed in their natural state. Polyethylene and polypropylene have a surface energy of 30 dynes/cm². For good printability. The surface must be treated in one of four ways.

Liquid printers are probably the least favorite option in the industry. They are limited in the range of plastics that can be successfully treated, and they are inconvenient to apply. Spraying or dipping, not wiping, are the preferred methods. Care must be taken not to inhale the vapors or allow the fluid to come in contact with the skin. Experimentation is necessary, but even then, changes in substrate batches can alter the primer's effectiveness.

Corona treatment uses a high-voltage discharge to change the surface energy of the substrate. Materials are treated in line using two electrodes - one over the substrate and one under. The electrodes generate a plasma that ionizes the substrate, altering its surface tension. The distance between the electrodes is critical and should remain constant.

Corona discharge treats films most successfully because the distance between the electrodes is small. Larger decorators may have such equipment in house or they may buy corona-treated films from their vendors. Sophisticated systems are available for corona treating three-dimensional objects very effectively. These are used where high volumes can justify the capital costs. The process will not work if there is any break in the surface being treated because the discharge will find the path of least resistance and short directly through the hole. As an alternative, three-dimensional components can be bulk treated in a chamber that is charged with an electrical plasma. This is a very effective method and will treat every surface of a molding no matter what the shape. Decorators can only justify these methods in house for a very high number of parts, however, because the capital expense is high.

Flame treating is the most widely used method of pretreatment. Like corona treatment, it may be done in house or by the substrate manufacturer. Flexible and reliable if carefully controlled, flame treating enables
uneven and curved surfaces to be treated. This process uses a mixture of air and gas such as butane, propane, methane, etc. For the flame to be effective, it must be oxidizing (that is, blue).

Correct flame control is very important. A basic flamer will do simple work, but for regular use and long production runs, specially designed flame-control systems are recommended. These are fitted with gas- and air-control valves to compensate for pressure fluctuations, ensuring that the mixture is always optimum. Flame-nozzle design is important usually featuring single or double rows of ribbon burners that give a more stable flame shape and characteristic. "Flame throwers" are inefficient and unreliable. Flame control and position of the item in the flame are critical, so setting up the flamer is very important.

In flame treating, flame shape is critical for the pretreatment to be effective.

Over-flaming will damage the surface of the substrate, while under-flaming will cause the ink not to stick.

Cold-gas plasma treatment is emerging as an efficient way to treat polymers, dramatically improving their surface properties for high-performance printing. In some cases, plasma treatment provides the only acceptable solution to these common surface treatment problems. The only disadvantage is the expense of the equipment, although some companies offer contract plasma treating.

Testing for correct pretreatment to ensure that a substrate has been properly pretreated, you must establish that the surface energy has changed. Kits are available that allow you to test the surface energy of the substrate by applying liquids with known dyne levels and watching the reaction.

**Testing surface**

Dyne kits allow you to determine the surface energy of a substrate by applying fluids with known dyne levels onto it and watching the reaction. If the surface energy of the substrate is higher than the surface tension of the testing fluid, it will flow evenly rather than break up into globules.

If the mixture spread evenly across the surface, then the surface energy of the substrate is equal or higher than the surface tension of the testing fluid. If the liquid beads up and forms into globules, however, then the substrate has a lower surface energy. These tests are essential for establishing that a material can be printed. They work no matter what form of pretreatment has been used.

Dyne-testing kits normally consist of six to eight fluids with surface tensions ranging from 28-56 dynes/cm². The lids must be firmly replaced after use, and gloves and goggles should be worn to prevent contact with the skin and eyes. Test kits are also available in felt-tip pen form, which are adequate for ensuring that the substrate has a certain minimum dyne level.

Having a dyne-testing kit is imperative for any pad-printing shop. In lieu of one, a few simple rule-of-thumb
Thumb tests can be tried. First, you can simply hold the object to be printed under running water and then remove it. If the substrate has been properly treated, the water will seem to wet evenly, then de-wet slowly. On an untreated surface, the water will bead up. Another, less reliable test is to mark the substrate with a ball-point pen. Stick a strip of Scotch tape on the pen mark and pull it off. If the substrate is correctly pretreated, most of the ink will adhere to the plastic instead of the tape. This test is far from ideal and should be used only as a last resort.

**Other factors affecting adhesion**
Surface pretreatment is a decisive factor when printing onto polyethylene and polypropylene. But other factors affecting adhesion, such as slip-additive migration, can't be detected from a dyne test. You could get favorable results in a dyne test and still suffer ink-adhesion failure. Also, two surfaces with the same treatment levels may show different ink-adhesion characteristics. You need to be aware of these possibilities when troubleshooting a printing difficulty.

If you are printing a polyolefin and pretreating it isn't an option, special inks are available that don't require pretreatment. These single-part inks require efficient post-treatment in the form of either IR, forced-air, flame, or UV drying that enhances the final characteristic of the relevant ink system. Without this post-treatment, the highly stable structure of the material makes satisfactory adhesion impossible.

**Properties of cured ink**
The substrate alone isn't enough information to determine what ink to use. You must know what is required of the cured ink film by the customer.

Color matching is a topic for another article, but a few basic issues should be mentioned. The starting point is either a sample of the color applied to the surface to be printed and/or a reference to a standard color specification, such as PMS, DIN, etc. Remember that the ink film in pad printing is very thin, and you often must print on a colored background that will affect the final color of the ink. Always check the printed color under different lighting conditions. Stability of color under UV light is very important. You'll find information on your technical data sheets regarding the properties of the pigments.

**Adhesion and abrasion resistance:** Cross-hatch tests, rub tests, tabor-wheel abrasion tests, etc., should all be specified before you select an ink. The classical comment “it mustn't scratch off” is not acceptable. The most recognized adhesion test is to cut a cross hatch through the cured ink in 4-mm squares.

**Testing Abrasion Resistance**
The familiar cross-hatch test, shown here on a cylindrical substrate, is the most common adhesion test in pad printing.

You then apply Scotch tape and remove it with a sharp pull at an acute angle to the surface. The amount of the ink remaining determines the level of adhesion.

**Resistance to chemical attack:** A printed part may need to withstand the effects of oils, solvents, acids, alkalis, or plain water. Probably one of the most arduous environments is a dishwasher, where there is a mixture of detergent, alkali, and hot water. I am not aware of any non-ceramic ink systems that will withstand dishwashing for extended periods. Another surprisingly aggressive material is melted snow. This contains a whole cocktail of chemicals that are collected as the clouds from and the snow falls through the atmosphere. Always check what your client needs the printed ink film to withstand before you start printing. Read the technical data sheet provided by your ink supplier. If in doubt, run tests with the ink and provide printed samples for your client to approve. If necessary, ask your ink supplier to run trials.
Weathering again: The technical data sheet will give you information on this subject. If weathering characteristics are critical, it is possible to carry out accelerated tests on the printed substrate. Either an ink supplier or an independent lab can conduct tests for you if you don’t have access to the equipment.

Special requirements: Food and toy applications are a good example, both involving ink that may be ingested. The toxicity level of pigments and resins used in such inks is very carefully controlled. Heavy metals such as cadmium are totally unacceptable, and the regulations are constantly becoming stricter, so seek advice from your ink supplier if you aren't absolutely certain.

Post-production processes
Any post-printing steps the part must go through could affect the ink performance. In screen printing, die-cutting and thermo-forming can both be problematic with certain inks. In pad printing, clear coating is a process to watch. The underlying ink must be fully cured and impervious to any solvents in the clear coat. The clear coat won't stick to under-cured ink, and it may cause the ink to bleed if the solvents aren't compatible.

If adhesion difficulties arise, it's important to check all of the following points:

- Was a mold release used in manufacturing the part?
- Were any plasticizers used by the molder?
- Has the molder changed the percentage of filler?
- Is the molder using recycled material?
- Is any grease or oil on the surface?
- Is the press operator wiping the image area of the substrate with a hand or finger and leaving greasy marks?
- Have the parts been stored at a low temperature and then brought into a higher-temperature environment? (This will cause unseen condensation on the surface.)
- Has the material in the part been changed without your knowledge?
- Are you using the correct ink?
- Has it been weighed out? Were additives like hardeners added in the proper ratios?
- Has the right thinner been used?
- Has anything been added by mistake (mineral spirits, water, etc.)?
- Was the ink well stirred before being mixed?
- Has the ink's shelf life expired?
- Has the ink been left in the press too long?
- Should you be pre- or post-treating?
- Does the substrate have an adequate dyne level for printing?

Putting these guidelines into practice

If you've been reading this series of articles, you know how important it is to control the balance of solvent in the ink so they evaporate properly. Ink manufacturers spend vast amounts of time and money developing and formulating inks to satisfy this criterion. Then what do some printers do? Pour the ink from a can into the ink reservoir without checking the label. They squirt in some solvent, and then try to print. When the ink doesn't transfer or stick, who is blamed? The ink manufacturer, of course.

Really, there is a better way. Imagine you're receiving a new order. You need some information about the job before you even begin thinking about which ink to use. This information should be on the work order and it might look something like this:
Substrate
- Base material: 15% glass-filled Nylon 66
- Color: Black
- Finish: Gloss

Ink requirements
- Color: PMS orange 021C
- Finish: Gloss

Test requirements
- Cross hatch 0.1-in. (0.25-cm) grid. Scotch tape applied, less than 10% removed.
- Resistant to ten rubs of a 1-in square (0.25 cm) felt pad soaked in mineral spirits, with a force of 2 lbs applied.

These factors would indicate the need to use a reactive-curing two component ink with some form of forced-air drying. Such an ink would give the necessary adhesion and withstand the rub tests. It will also be necessary to apply several prints, probably three, to get sufficient density of the bright orange ink on the black substrate. The ink will have a gloss finish because the substrate has one. Forced-air drying will enhance the cure of the ink film and prevent dust from collecting on the surface before it dries.

Before the job goes to production, tests are conducted to check the ink/substrate combination. The trials not only establish that the printing and drying recommendations work, but also the mix of solvents needed in the ink to give optimum printing performance.

Now, on to production. The operator is given the production-control card, which details all the setup and ink instructions. He gathers up the necessary materials and put on any protective clothing required (goggles, gloves, and an apron). He reads the labels on the ink, hardener, and solvents to double-check the production control card. He also checks the date to ensure that nothing has passed the shelf life.

He opens the ink can and stirs the contents vigorously. He also opens and stirs the hardener. He places a suitable container on the scales and puts the stated amount of ink in. He then adds the hardener to the correct ratio - by weight - and stirs it in. Then adds the mix of solvents, carefully stirring to ensure complete dispersion in the mix. (At this stage, some shops might use a viscometer to check the viscosity. If your mixtures are correct by weight, the viscosity will be acceptable in any case.)

The operator then pours the specified amount of ink into the ink reservoir. He keeps the remainder in a closed container for use throughout the run. He makes the other press settings as specified by the production control card. Surprise, surprise: The first print is acceptable. Assuming the press operator maintains the solvent balance during the day by adding measured amounts of solvent at specified intervals, the press will run right on through.

Depending on the ink system and the ambient temperatures, the ink will have to be completely replaced with a new batch in 8-10 hr. This is because a two-component ink will begin curing in the ink reservoir and its printing characteristics will change. In very high ambient temperatures, it may be necessary to change the ink more often. It's very important to estimate a two-component ink carefully, since anything not used that day should be disposed of correctly and is expensive to waste. If the job had called for a single-component ink (no catalyst), the ink wouldn't cure in the reservoir and could be used on press for a much longer period. I would still recommend changing it after 48 hr, as contaminants can build up that will alter the ink's properties. Oxidation-curing inks may also undergo chemical changes.
By the way, it is not recommended to leave a two-component ink in the sealed cup for extended periods, especially overnight, as they gel if they are not agitated and will cure completely if left in the cup. Care must also be taken when using reactive ink on screened clichés. Any trace of ink left in the etched portion of the cliché overnight will cure and be impossible to remove the next day. This applies to a greater or lesser extent with any part of the machine or jigging.

Conclusion
In pad printing, the ink may be the most important element of the process, yet it is constantly abused. Always carry out tests on the substrate before going into production. Materials do change and problems can occur. Take a systematic approach to choosing, testing, preparing, and using your inks, and you'll see a world of improvement in your pad-printing operation.

Rules of Using Ink
- Read the technical data sheets.
- Read and understand the Health and Safety Data Sheet.
- Always wear protective clothing, gloves, and goggles when mixing inks.
- Ensure that ventilation is adequate at all times.
- Stir ink and hardeners before use.
- Use only specified solvents.
- Weigh the ink, solvent, hardener, components, and mixture.
- Do not use inks or hardeners that are past their shelf life.
- Seal partly used cans of ink. Their shelf life is reduced once opened.
- Keep unused mixed ink in a closed container.
- Do not use mixed two-component ink after pot life is expired.
- Do not use two-component inks in closed-cup printing system.
- If single-component ink is used, continuously change every two days.
- Never Mix ink types to achieve a color match.
- If ink splashes onto your skin, wipe off excess with tissue or cloth and wash with soap and water or proper hand cleaner.
- Never use thinners to remove ink from skin.
- If ink or solvents enter your eye, irrigate with water for 15 min and seek medical advice immediately.
- In case of swallowing, do not induce vomiting. Seek medical advice immediately.
- In both the above cases, take the Health and Safety Data Sheet and the Technical Data Sheet to the medical authority.

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