PAD PRINTING 101: The History, The Machines, Their Drive Systems and Accessories

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HISTORY

The Swiss invented the pad transfer printing process in the late nineteenth century. The theory behind the pad printing process actually borrows from the screen, rubber stamp and photogravure printing processes.

In the beginning copper plates were etched with recessed images as in the photogravure process. The surface of the plates were then flooded with ink and wiped clean similar to the way a screen is flooded and squeegeed in the screen printing process. A pad was then compressed first onto the plate to pick up the image, then onto the substrate to transfer the image, similar to rubber stamp printing.

Pad printing was mainly limited to Europe until the early 1970s, when a few manufacturers introduced their products to North America. For the rest of that decade and half of the next, pad printing competed directly with hot stamping and screen printing for industrial decorating business.

As people began to see the benefits of pad printing versus the other two processes, a niche developed. Companies using hot stamping quickly realized that pad printing could decorate the majority of their products faster and with less wasted material. Screen printers found that pad printing worked better for decorating three-dimensional objects, including those having compound angles. The niche quickly turned into a new industry. By the end of the 1980s, the number of pad printing equipment manufacturers and distributors more than doubled in the United States. Early in the 1990s the Screen Printing Association International expanded to incorporate the pad printing process (as well as a few others) and changed their name to the Screenprinting and Graphic Imaging Association International.

The list of potential applications for pad printing is seemingly endless. The average

People outside the industry usually ask, "What kind of pads do you print?" Nine times out of ten I can pick up an object within arm's reach to use as a prop to accompany a brief explanation.

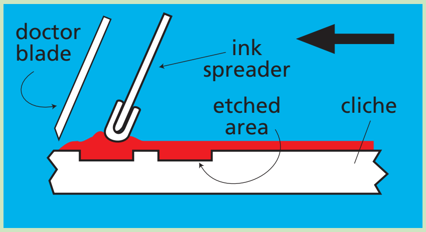


Figure 1

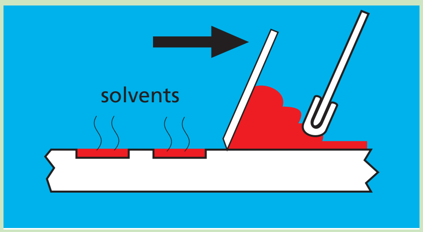


Figure 2

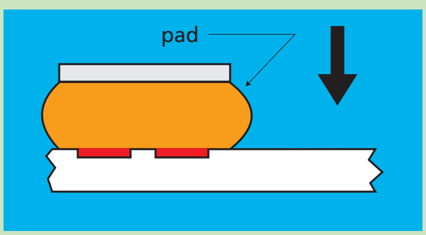


Figure 3

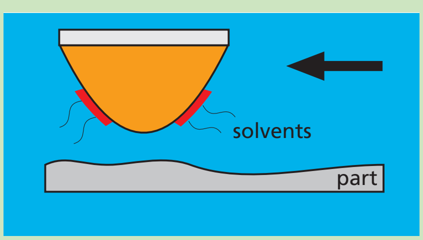


Figure 4

person probably comes into contact with dozens of pad printed products on a daily basis without knowing it. Here are just a few things that are commonly decorated with pad printing: alarm clocks, shower heads, electric razors, toothbrushes, coffee makers, coffee cups, toasters, oven knobs, radios, television housings, remote controls, telephones, watch dials, computer housings, monitors, keyboards, diskettes, pens, eyeglass frames — the list goes on.

It really is amazing when you stop to think about all of the products that are decorated with pad printing. In fact, when I tell someone outside of the industry that I am involved with pad printing they usually ask, "What kind of pads do you print?" Nine times out of ten I can pick up an object that is within arm's reach to use as a prop to accompany a brief explanation. You have no idea how many times I've received strange looks from passers-by when they encounter me in the store critiquing the print on some toy, tool or appliance.

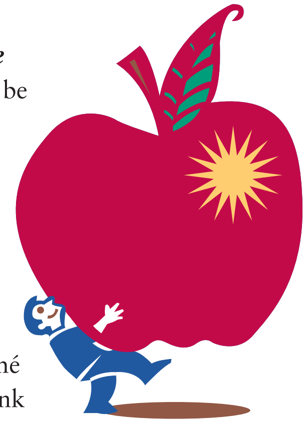
Pad printing is part art and part science. To expect to be able to purchase a machine, choose the right cliché, ink and pad and then print successfully overnight is unrealistic. While you don't have to have experience with any printing process or be a chemist to succeed, you do need to take the time to learn how the process works, and how to control the variables involved with each application.

PRINCIPLES OF OPERATION

All pad printing machines are built around one of two basic principles of operation. Those two principles are commonly referred to as the "open principle" and the "closed principle."

The diagrams starting at the left illustrate how the pad printing theory is applied in the case of the open principle. Machines applying the open principle are commonly referred to as "open systems." Open systems are the older of the two types.

Open Principle



The image to be transferred is etched into a printing plate, commonly referred to as a cliché. Once mounted in the machine the cliché is flooded with ink (Figure 1). The surface of the cliché is then doctored clean, leaving ink only in the image area. As solvents evaporate from the surface of the ink in the image area, the ink's ability to adhere to the silicone transfer pad increases (Figure 2). The pad is positioned directly over the cliché, pressed onto the surface to pick up the ink, and then lifted away (Figure 3).

The physical changes that take place in the ink during flooding (and doctoring) account for its ability to leave the recessed image area in favor of the pad. After the pad is lifted away from the cliché to its complete vertical height there is a delay before the ink is deposited onto the substrate. At this stage the ink on the pad surface undergoes physical changes as solvents evaporate from the outside of the ink layer, increasing tack (Figure 4).

The physical changes that take place within the ink layer during the print stroke result in the ink developing more of an affinity for adhering to the substrate than to the pad. The pad is then compressed onto the substrate, transferring the image (Figure 5). Even though the pad compresses considerably during this step, the contour of the pad is designed to roll away from the substrate's surface rather than press flatly against it. A properly designed pad, in fact, will never form a zero degree angle of contact with the substrate. Such a situation would trap air between the pad and the substrate, resulting in an incomplete transfer of the image.

The pad lifts away from the substrate and assumes its original shape. When the variables involved with all five steps are properly controlled, the pad should lift away clean and ready for the next print cycle (Figure 6).

Closed Principle

The closed principle differs from the open principle in that the ink is not directly exposed to the air. In closed systems the ink is inside of a “sealed” container, usually referred to as an “ink cup.”

Ink flooding occurs while the ink cup is positioned over the etched image area. The sharp edge of the ink cup, commonly referred to as the “doctoring edge” or “doctoring ring” acts like the doctor blade in an open system. Doctoring occurs when the ink cup slides across the top surface of the cliché in some designs. In other designs the ink cup remains stationary and the cliché reciprocates under the doctoring ring. The following diagrams (Figures 7-12) show the cup moving instead of the cliché. In either case the end result is that the top surface of the cliché is doctored clean and the recessed image area is left flooded with ink. From that point the theory applied is the same as an open system.

Basically an open system allows you to use more of the cliché’s total surface area for the image. They are also somewhat more versatile in that you can simply change the size of the inkwell and accessories to print using varying cliché sizes.

Closed systems generally allow better process control since the inks are not directly exposed to the air. Solvent evaporation, the effects of temperature and humidity, and airborne contamination are all reduced in closed systems.

Closed systems typically have fewer parts and require less ink, which translates into faster cliché and/or color changes and faster cleanup.

Ink cup designs are usually proprietary. Some ink cups are of one-piece construction, whereas others require some assembly. Since some types of inks generate gases during printing, some ink cup designs feature gas-venting systems, whereas others do not. In most applications, however, the venting of gases is not necessary.

PAD PRINTING MACHINES

There are many types of pad printing machines which apply either the open or closed principle. Most pad printers pick up and transfer the image vertically (Figure 13). These are commonly referred to as standard, or standard vertical pad printers.

Variations on Standard Vertical Machines

A few manufacturers modify the ink cups in standard vertical machines by equipping them with inflatable diaphragms. When the diaphragm is pressurized the cliché can be flooded even if the machine is completely inverted (Figure 14). Machines using these cups are usually mounted to automated systems where parts are printed on several different sides in one cycle. While these cups are handy in that they allow some standard vertical machines to print on any angle, they can be tricky to set up and maintain, and their maximum diameter rarely exceeds 60 mm.

Another variation on standard vertical design is the carousel machine. Synchronized rotation of separate cliché and pad mechanisms allows for multiple color printing on a stationary substrate (Figure 15).

Standard vertical machines can also be modified to print 360 degrees around a cylindrical object in certain applications. This can be accomplished two different ways. In both cases the pad picks up the image and travels to the end of the print stoke (or down position). The first method (Figure 16) rolls the cylindrical part, nested on a mandrel, along the length of the pad by means of a gear. The second method (Figure 17) shuttles the pad across the top of the part.

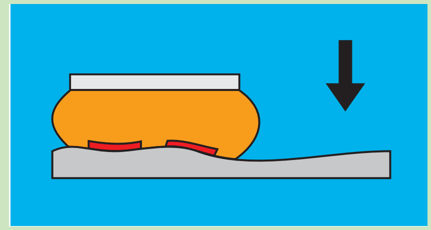


Figure 5

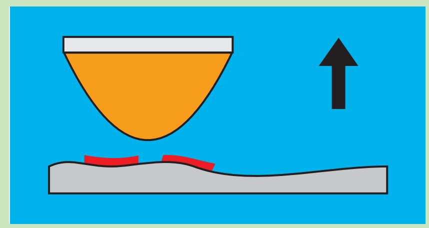


Figure 6

Step 1: Flooding

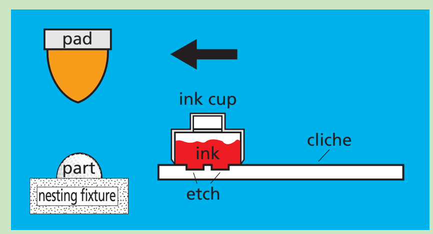


Figure 7

Step 2: Doctoring

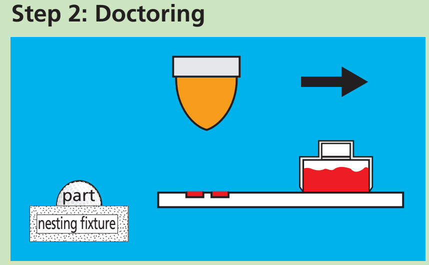


Figure 8

Step 3: Image Pick Up

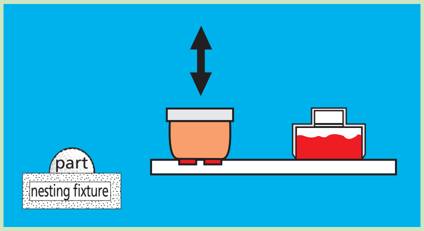


Figure 9

Step 4: Print Stroke

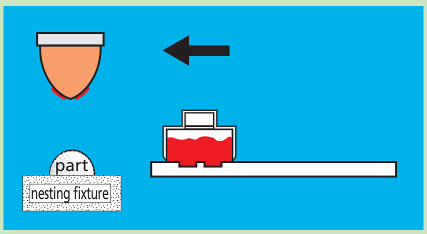


Figure 10

Step 5: Ink Deposit

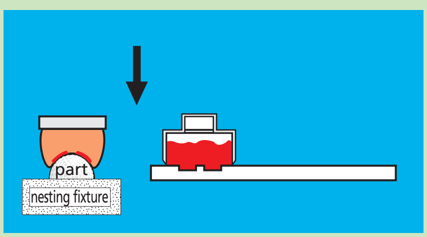


Figure 11

Step 6: Pad Release

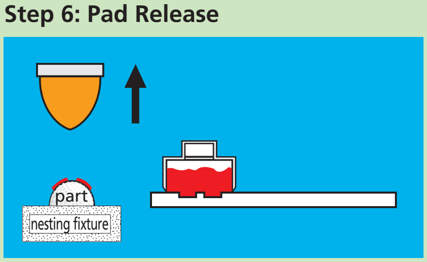


Figure 12

Horizontal Machines

Another popular variation on standard vertical design is the horizontal pad printer. Machines of this type flood, doctor and pick up like a standard vertical machine, then actuate to print horizontally (Figure 18). These machines are useful for printing larger images horizontally, but they are much slower than most vertical pad printers that utilize pressurized ink cups.

Sliding Ink Cup Machines

One of the newer closed system evolutions is the "sliding ink cup" machine. These machines feature long, narrow clichés that are mounted in the X-axis, or perpendicular to the axis along which the pad travels (Figure 19). Sliding ink cup machines allow wide images to be printed with a closed system. They work great for printing things like bats, hockey sticks, racquets and golf club shafts, hoses and tubing, or for printing several smaller parts nested side by side.

Rotary Machines

Rotary pad printers come in two varieties. There are vertical and horizontal rotary machines. Either type is capable of printing on flat or cylindrical objects using cylindrical "drum" clichés and round transfer pads.

Vertical Rotary Machines

A vertical rotary machine (Figure 20) can print flat surfaces (like the top of bottle caps) when the objects to be printed are moving along underneath the rotating pad. In applications such as this several rows of parts can be printed simultaneously by using a drum cliché with multiple images and multiple pads.

Vertical rotary machines can also print cylindrical objects by any one of several methods. Single objects can be nested on a mandrel and shuttled to locate bottom center on the pad. The part is then rotated during image transfer either by the mandrel being gear driven, or by the force of the transfer pad.

Cylindrical objects (for example, pencils) can also be conveyor fed under a vertical rotary pad printer for 360 degree printing (Figure 21).

Horizontal Rotary Machines

Horizontal rotary machines (Figure 22) can print on flat or cylindrical parts that are vertically nested. The illustration shows cassette tapes being printed on two sides. Cylindrical objects such as lipstick canisters may also be printed using this method.

Manual Machines

A few manufacturers offer small, manually-operated machines. Manual machines feature a hand-operated slide with a pad at one end and an inkwell at the other. Some manual machines have simple, cam-operated doctoring systems that automatically doctor the cliché when the operator slides the carriage, while others require the operator to actuate a lever connected to the doctor blade assembly with one hand while sliding the carriage with the other hand. In the past manual machines operated mostly on the open principle, however several manufacturers have recently introduced new or revised models that feature sealed ink cups.

Figure 23 and Figure 24 illustrate a typical manual machine.

Machine Drive Systems

Pad printers are powered by several different types of drive systems including: electro-mechanical, stepper motor driven, electro-pneumatic, electro-hydraulic, pneumatic and manual.

Electro-Mechanical

Electro-mechanical machines are electronically controlled cam-driven machines. This type of machine is generally most expensive up front, and tends to lack some adjustability. Electro-mechanical drives are extremely consistent regardless of machine speed and print mode. (i.e. single or double print, etc.) These machines also have little difficulty compressing pads of any reasonable size, regardless of durometer. Since air is not necessary there is no need for an air compressor. This can translate into lower operating costs and less noise.

Stepper Motor Driven

Stepper motor drives have programmable adjustments for each individual stroke for both length and speed. A stepper motor basically translates 360 degrees of motor rotation into a given number of "steps." The operator can then program the number of steps he or she wants the machine to travel. These machines operate with little or no vibration, and are typically very quiet. As is the case with electro-mechanical machines, no air is necessary. Therefore, while these machines may be more expensive than an electro-pneumatic or pneumatic machine up front, the costs of operating it may actually be lower.

Electro-Pneumatic

Electro-pneumatic machines are electronically controlled air driven machines. The majority of the machines in the industry today are of this type. Less expensive to manufacture, machines with this type of drive are quite reliable provided you are operating with clean, dry air at the proper pressure. At high speeds some pneumatic drives can have difficulty with consistency from print to print, especially in multiple print modes. This is usually due to the pneumatic cylinders not having enough time and/or air pressure or air volume in between cycles to completely "re-charge." Sometimes the addition of accumulators can alleviate this problem. There is a reason why most machines have this type of drive, and that reason is because for 99% of the applications out there it is the most cost efficient way to go.

Pneumatic

Fully pneumatic machines are somewhat rare, and usually limited to closed systems. (I've never seen a fully pneumatic pad printer that wasn't a closed system.) Less expensive still than their electronically-controlled cousins, these machines are best applied to automations where they can run all day without stopping. One special benefit of fully pneumatic machines is that they are explosion resistant due to the lack of electronics.

Clean, dry air is important with any air-driven equipment, electronically controlled or otherwise. Wet, excessively oily and dirty air can significantly reduce the life of the machine. Most pad printers require a constant air pressure in the ballpark of 85-100 P.S.I., or approximately 6 Bar. The volume of air readily accessible can be of importance, especially when double printing, or when running a pneumatic printer and a pneumatic conveyor table or shuttle off of the same airline.

Manual

Manually operated machines are small and inexpensive. Some models have cam-operated doctoring mechanisms, and some don't. This feature is well worth the extra few hundred dollars they usually cost. Image sizes are limited to a few square inches since compressing a pad any larger would require Herculean strength. These machines are a nice alternative to starter level electro-pneumatic machines for those who are experimenting with pad printing, or who are doing small volume jobs that aren't critical. Some manufacturers offer trade-in deals when upgrading from manual to automatic machines.

Electro-Hydraulic

Electro-hydraulic machines are very rare. These machines are usually more expensive than even electro-mechanical machines to manufacture. While these machines are slow, they can supply a lot of compression for those gigantic

Vertical Machine

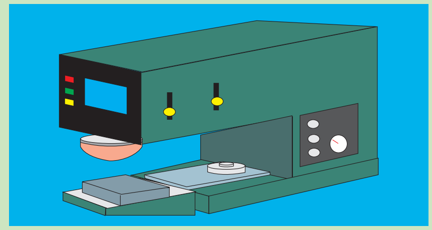


Figure 13

Pressurized Ink Cup

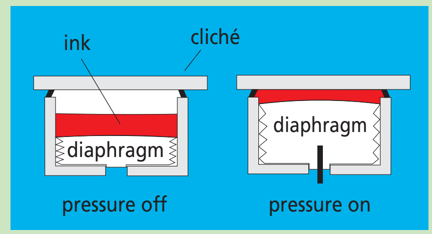


Figure 14

Carousel Printer

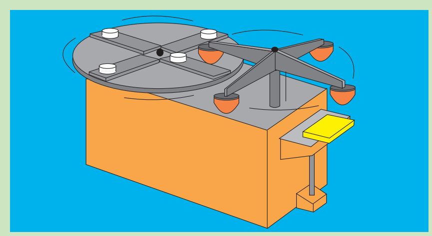


Figure 15

Method 1: Moving Part

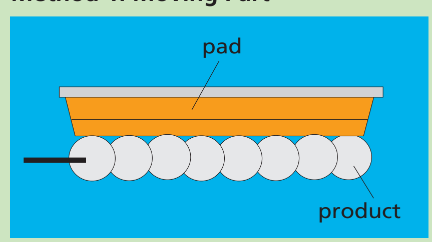


Figure 16

Method 1: Moving Pad

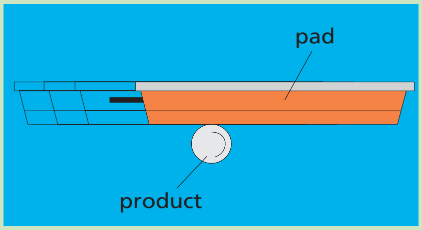


Figure 17

Horizontal Machine

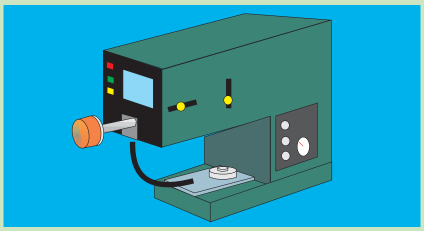


Figure 18

Sliding Ink Cup

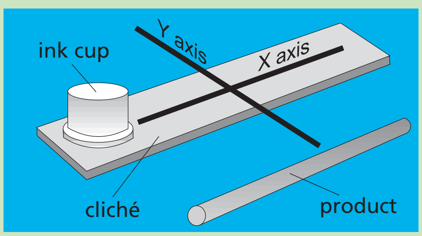


Figure 19

Vertical Rotary

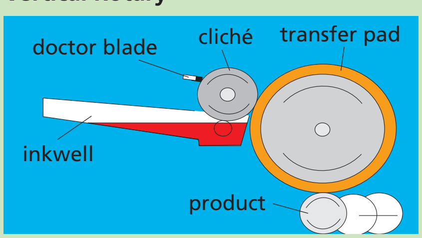


Figure 20

Vertical Rotary

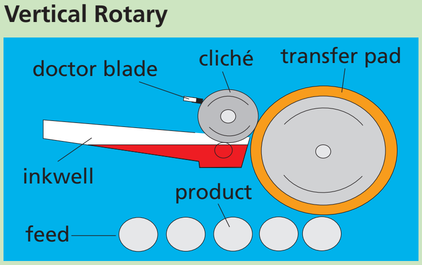


Figure 21

images that absolutely can't be printed by any other means.

OPTIONS AND ACCESSORIES

Multiple Colors

Most manufacturers offer standard vertical machines in one through four or six color configurations.

Multiple color open systems can have multiple clichés, or one cliché in a split inkwell. Independently adjustable clichés are, in my opinion, desirable over having all of the colors on a single cliché. The benefit of independent clichés is simply the ability to absorb potential image-to-image and/or image-to-part location problems more easily.

Multiple color, closed systems can also have single or multiple clichés. A few manufacturers offer small (60 mm) multiple color ink cups (commonly referred to as 'split ink cups') that allow you to print two or three colors. The limitation is that the colors are going to have to be side by side, unless your machine can pick up once, then stroke the print two or three times. In that instance, you can shuttle the part to print colors on top of one another. The other limitation is that these cups are difficult to manufacture, and thus expensive.

Shuttles

There are basically four kinds of shuttles: pneumatic, electronic, stepper motor driven and manual. Pneumatic shuttles are less expensive, and more popular. Pneumatic shuttles can have multiple positions by means of either multiple cylinders, or a single, more expensive cylinder with magnetic brakes. One has to be very careful to avoid any fluctuation to air pressure when working with parts of a critical nature on pneumatic shuttles.

Electronic shuttles have programmable, servo-driven motors. These shuttles are more expensive than their pneumatic counterparts, and somewhat hard to find.

Stepper motor driven shuttles can be programmed to travel a desired number of steps between prints. Stepper motor and electronic shuttles will typically last longer than pneumatic shuttles.

Manual shuttles are used for low volume jobs where the registration of colors is not critical.

Rotary Tables

Rotary tables can also be electronic, stepper motor driven or pneumatic. Accuracy and price are determining factors. Electronic and stepper motor driven rotary tables are more expensive than pneumatic ones, but they can move weight more accurately. Rotary tables can be of just about any reasonable diameter, allowing anywhere from two to a dozen or more fixtures to be attached.

Some manufacturers have modular rotary systems with up to four independently adjustable machine mounting stations. Depending upon the application, one, two, three or all four machines can be used simultaneously, turned off individually, and even rotated 180 degrees on their mounts to operate alone, allowing more than one job to run at the same time.

Racetrack Conveyors

Racetrack conveyors are standard equipment on many multiple color machines. Pneumatically driven in most cases, racetracks can have several nests or fixtures. If necessary cams can be attached to allow the nests to rotate in between stations for printing multiple sides on a given part. These systems are rarely used outside of the pad printing industry.

Over-Under Conveyors

Over-under conveyors are usually chain driven or precision-link mechanically driven. In most cases parts simply fall off the nests into a container at the end of the line, or are transferred to separate conveyor for subsequent operations. A few manufacturers use the bottom of under-over conveyors for secondary operations.

Walking Beams

Walking beams are a mechanical means of moving parts from one print station to another. Walking beams are limited in that they usually require that the part be picked up, moved over and located against a stop of some sort for each printing operation. In most multiple color operations it is not recommended that the part be moved in this fashion.

Hot-Air Dryers

Hot air dryers are common on racetrack conveyors and rotary tables alike. Even though most pad printing inks dry to the touch within a few minutes, most people prefer to have the additional drying equipment, especially if they are using two component ink or multiple color printing with a lot of coverage, or at high speeds.

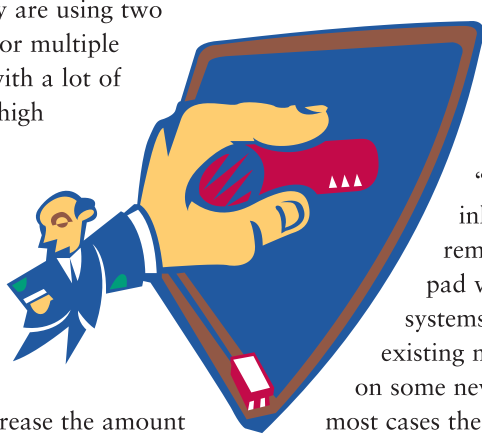
Air Blasts

In many applications, single and multiple color alike, it is necessary to increase the amount of airflow over the surface of the part and/or the pad in between prints to speed drying and increase adhesion of subsequent colors.

Usually a separate compressed air line and regulator are necessary, as are separate in-line regulators for each individual branch.

Flame Treating Equipment

Certain substrates require pre-treatment to increase their “wettability,” or ability to accept the ink and allow it to flow. Materials like LDPE, HDPE, PET, PP, PVC, EPDM and EVA are examples. Flame treating equipment requires propane or natural gas, so one of those two needs to be available near the machine.



Corona/Plasma Treating Equipment

Instead of using flame, corona and plasma treating equipment uses electrical current to produce an ion rich discharge that increases the wettability of the surface exposed. This equipment is more expensive than flame treating equipment, but it is faster, cleaner and doesn’t require any fuel, only electricity.

Static Control Equipment

Sometimes static is a problem. Packaging materials, plastics, the friction of the machine, or even low humidity can generate static. When necessary static control equipment like de-ionizing air nozzles and air knives can be added to the pad printer or feed systems.

Ink Residue Removal Systems

Also known as “tape-off,” automatic ink residue systems can remove debris from the pad very quickly. These systems can be add-ons to existing machines, or built-ins on some newer machines. In most cases the frequency of tape-off (cleaning) is programmable. Usually the tape-off occurs after image transfer. After the pad prints and returns to the “up” position a slide mechanism positions a “tray” of tape adhesive side up under the pad. The pad compresses on the tray quickly, the slide moves the tray back out of the way, and the next printing cycle starts.

Ink Pumps

Ink pumps are sometimes used on automated open systems. Particularly useful on vertical rotary pad printers, ink pumps automatically control ink viscosity. Usually the ink drains from the lowest point in the ink well into a container where thinner is automatically added and mixed into the ink. The ink is then pumped back up into the ink well.

Horizontal Rotary

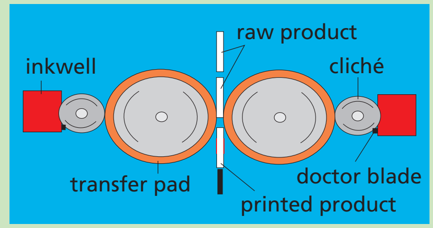


Figure 22

Manual Machine
(In Image Pick-Up Position)

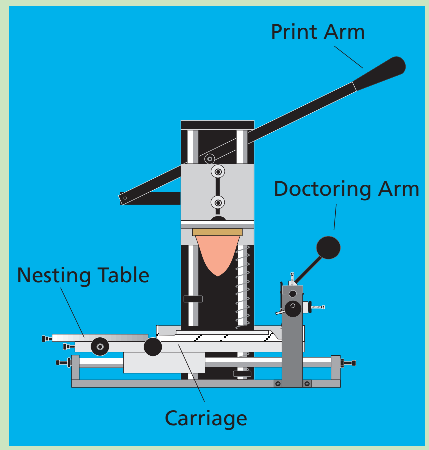


Figure 23

Manual Machine
(In Print Position)

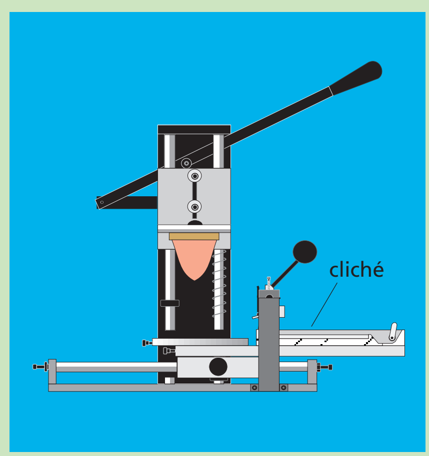


Figure 24

Thinner Metering Systems

Automated closed cup machines can have thinner metering systems added to continuously add thinner to the ink cup. These systems simply drip a predetermined amount of solvent into the top of the ink cup at regular intervals. Unless the ink cup has some feature that allows the thinner to be mixed into the ink, the thinner just sits on top of the ink, having very little effect on viscosity.

Pad Shuttles

Pad shuttles can be a less expensive alternative to the purchase of a larger machine in some applications. Using a split pad, a pad shuttle can, in some cases, print an image that would otherwise exceed the cliché or ink cup's maximum image area. For example, let's say you have two images of the same color that must print with their respective center lines being 45 millimeters apart. When the etch is separated by this dimension the two images don't fit within your machine's maximum image area. If these two images fit when separated by, for example, 30 millimeters, then you could etch them that way, pick them up with two pads butted together, and shuttle the two pads apart to achieve the desired 45-millimeter separation prior to image transfer.

Pad shuttles can also be used to print two images on two different sides of the same part when both images, etched side by side, are picked up at the same time by two separate pads. After image pick up the pads move along the X-axis to position the first print. After the first print, the nest rotates while the pad shuttles into position for the second print. In order for this to work, your machine needs to be able to pick up once and print twice, and you must have both a pad shuttle and a rotating nesting fixture. You can also print two colors this way if you have a two-color ink well on a one color machine.

Nesting Fixtures

All too often nesting fixtures are an afterthought in tooling up for a job. In pad printing it is necessary for the part to be properly supported, especially at critical stress points and areas where the forces of pad compression are greatest. The nests also need to be ergonomically correct (worker friendly) and where several nests are necessary, within a few thousandths of an inch of being exactly the same. In some applications the type of pad to be used must be taken into consideration when designing the nests.

In the interests of saving time and money it is sometimes tempting to go to the tool maker down the street to have your nests built. That is fine, provided that your tool maker has experience dealing with pad printing. On several occasions I have seen quality problems result from a lack of pad print process knowledge in the design of nests, especially on automated systems.

Pad printing equipment manufacturers should know how to design and build nesting fixtures correctly. Let them build your nesting fixtures, at least until you become proficient enough to be able to educate the tool maker down the road.

Of course not all parts are critical enough in nature to warrant having someone build your nests. Some parts require little more than double-sided tape or a lump of modeling clay as a nest. A lot of people make their own nests for one-up printing jobs by using automotive body filler. You can find or build a container, mix up the filler, pour it into the container then seat your part in at the angle you want. (Spray the part first with a light lubricant so you can get it out of the filler after it cures.) After half an hour, the filler has cured enough for uneven surfaces, tight corners and rough edges to be sanded away for a reasonably consistent fit.

Safety Guards

Operator safety is everyone's concern. Some pad printers don't require any safety equipment while others require complex enclosures or light curtains. Most automatic machines come with standard safety guards or shields that are effective and don't interfere with the efficient operation of the printer.

In some manufacturing environments I have seen perfectly good machines rendered almost useless by the addition of poorly designed safety enclosures. Unfortunately there are individuals who will hurt themselves regardless of anything you do in an attempt to prevent it. Common sense can't be taught, but it can be made a requirement.

If you're responsible for purchasing equipment or making safety policy decisions, consult with everyone involved: operators, supervisors, the equipment manufacturer and OSHA regulations to ensure that your new machine will be both safe and effective.

FOR MORE INFORMATION

Keeping abreast of technological advances in pad printing is a bigger challenge today than ever before. In an effort to educate existing and potential pad printers, a generic, informational website has been created on the Internet at http://www.padprinting.net. ■