FEATURE

UV-Lamp Systems for Moving-Head Digital Inkjet Platforms

By Adrian Lockwood

Since 2000, the advent of Piezo "drop-on-demand" printheads, capable of jetting UV-curable inks, has led to a well-documented and dramatic increase in the use of digital imaging technology in place of traditional impact printing methods. This increase is none more so than in the screenprinting industry, where the ability to economically produce short-run, point-of-purchase (POP) 2- or 3-D displays with machines capable of printing onto rigid as well as flexible roll-to-roll substrates. The installation of flatbed scanning UV-inkjet platforms has more than doubled each year, while at the same time, there has been a decline in sales of traditional screenprint machines. It is estimated that in this year alone some 400-500 new flatbed UV-inkjet platforms will be installed worldwide. Figure 1 shows a 3 m x 3.5 m flatbed UV-inkjet printer.

FIGURE 1

A 3 m x 3.5 m flatbed UV-inkjet printer

At the same time, a dramatic growth in static UV-inkjet applications such as component marking and encoding and variable data printing for addressing and labelling as also occurred. These static applications have been able to readily adopt existing UV-lamp technology for curing solutions. However, the moving head X-Y plotters/grand format industrial graphic printers initially struggled to find appropriate lamp units.

The Requirement for Special UV-Lamp Units

A typical large-scale industrial platform (maybe 60-100 inches wide) is not dissimilar in operational principle to a desktop printer, where the media is fed beneath an array of printheads that scan from side to side, building up the image. The final printed image is formed from millions of miniscule ink droplets jetted at high speed onto the media or substrate. In this instance, the final product may be the vinyl 'tilt-side' of a truck, an advertising banner for a building, or the glass front of a commercial refrigerator.

The nature of the jetting process using drops, as small as 5 Pico litres (p.L.), requires UV-inkjet ink to be extremely low in viscosity and to flow readily at the operating temperature of the printhead. Therefore, to protect the integrity of the image and to avoid colors from merging or dots from flowing and growing, the ink droplets need to be frozen or cured immediately after printing. The UV lamps must be placed as close as possible to the printheads and move with them, rather than allowing the whole image to be completed and then cured.

In static UV inkjet and traditional printing applications, the UV lamp is fixed in position and does not move, making the size and weight of the lamp less of an issue. In scanning X-Y axis inkjet printing, the need to move the lamphead with the printheads means that size and weight are an issue. Modern printers accelerate the printheads to speeds up to 80 inches/sec (400 ft/min). Heavy UV lampheads strain the servo drive mechanisms or require costly up-rated servos. The print quality relies on the accuracy of the servo drive mechanism—the lighter the overall weight of the print engine the easier this is to achieve. Furthermore, large or bulky lampheads will not physically fit in-line with compact printheads. Typical UV-lamp units for graphic arts such as used in modern screen, flexographic and offset printing were evaluated; however, they tended to be too big and heavy for use in moving-head inkjet applications.

First Generation Inkjet Lamp Systems

First generation, purpose-built inkjet lamp units replaced extrusions with fabricated aluminium structures, yielding an overall weight savings up to 70%. These systems also included self-contained cooling systems within the lamp unit so as to eliminate hoses or ducts trailing across the machine.

Constant shuttling means that the lamp units must be resistant to vibration and able to withstand high-lateral forces during acceleration/deceleration on the order of 2-3 G without falling apart or shattering the UV bulb.

The UV-lamp units scan the printed inks at a height above the media less than 0.2 inches (5mm) and at speeds up to 100-inches-per-second. (2.5 m/sec), thus airflow from the lamp cooling could readily disrupt the ink drop pattern. Therefore, an isolated air system is necessary—typically in the form of a quartz exposure window—to seal off the curing zone. Figure 2 shows a pair of all alloy lamp heads for an inkjet printer with a cure width of 3.5 inches, a self-contained cooling and isolated air system, delivering up to 1.7 W/cm^2, yet weighing less than 4.5 lbs.

High-Speed Shutters

Printheads are irreparably damaged when UV light reflects back into the printheads from the media or machine parts. This poses one of the biggest problems with new generation UV-flatbed printers. Printheads are the single most expensive components in a printer. When printing onto thin materials, the low-scanning height of the lamps normally does not allow sufficient angle of incidence for UV light to reflect back into the printheads.

FIGURE 2

Alloy lamp heads for an inkjet printer

Piezo inkjet printheads in particular are also notoriously sensitive to external electrical noise due to their high-firing frequency and rate of data transfer, which can 10-20 Khz. With the UV cabling often running parallel to the printhead signal cables and the UV-lamp units mounted alongside the printheads, great care must be taken to eliminate electrical RF interference. Likewise, all of the UV lamp's electrical interconnections with the main power supply must run in a drag chain system, requiring the use of suitably rated, special high-flex cables that can withstand constant bending and flexing.

However, in applications involving the printing of thick materials, or where the print engine can scan beyond the bed of the machine, this becomes a serious problem.

Printhead damage (nozzle blocking) can occur even with very small amounts of reflected UV, and methods such as momentarily reducing lamp output down to a very low level (such as 10 or 20%), while the lamps are not above the media, has not proved to be a reasonable solution to this problem. Since neither arc nor microwave UV lamps can be switched off and back on again in the space of 1-2 seconds, the most effective solution has been the use of mechanical shutters to block UV exposure when the lamp units are not above the media. Pulse Xenon or "flash" systems have been extensively tested, but have generally failed to deliver a satisfactory cure under the specific operating conditions of these inkjet platforms.

Shutters for UV-lamp units are nothing new. Traditional lamp shutters open when printing commences and close when printing stops. However, on an inkjet platform, the shutters may cycle every two seconds or less, which means that on average they would be subjected to a duty cycle 300-500 times more rigorous than, for example, an average web fed offset or flexo press—perhaps up to 4-million cycles per shift per annum. With the additional requirement of having to fully open or close in less than 100 ms with very low inertia while experiencing high lateral G forces at high temperature, totally new designs and materials for UV-inkjet lamp shutter mechanisms have become necessary. The most successful solutions to date have been electrically operated shutters that combine speed with durability.

Figure 3

An example of a second generation product

This lamp head with a cure width of just over 2 inches, delivers up to 250W/inch of output at an irradiance of 2.1 W/cm² and equipped with self-contained cooling complete with internal fans.

Second Generation Inkjet Lamp Systems

In the last 12-18 months, the drive to produce even smaller and lighter inkjet UV-lamp units combined with the impending development of more office-based UV platforms has led to the adoption of some novel materials for construction of second generation products (at least novel as far as the manufacture of UV-lamp units is concerned). Materials such as high-temperature automotive composites, carbon fiber, and titanium and ceramics have recently been utilized. An early example of a second generation product can be seen in Figure 3, which shows a lamphead with a cure width of just over 2 inches, which delivers an irradiance of up to 2.1 W/cm^2 and is equipped with self-contained cooling complete with internal fans. This lamp system weighs only 20 ounces.

UV-Inkjet Cure Characteristics

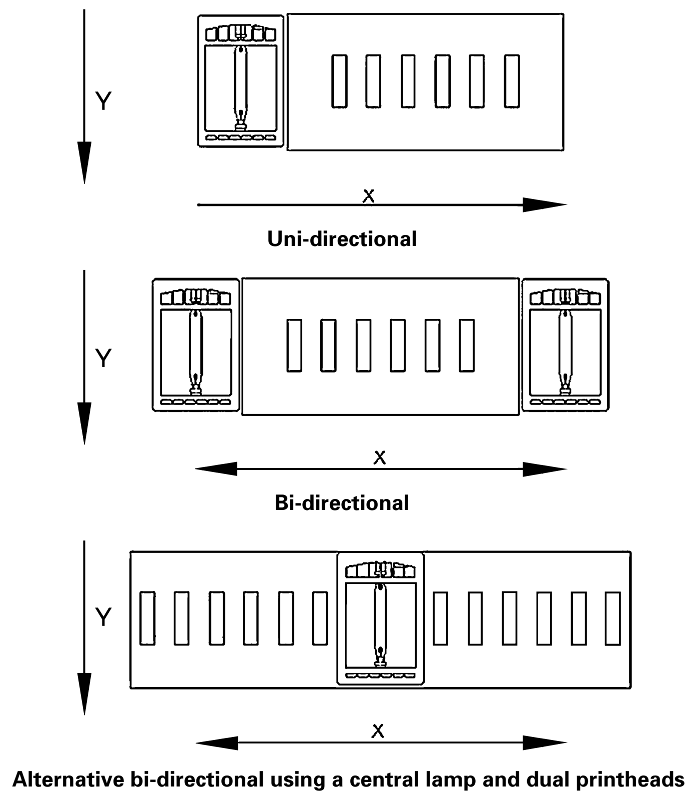
Static-head inkjet printing, along with most other traditional graphic UV-printing applications, usually requires the printed image to be fully cured and permanently fixed after passing beneath the UV-light source. However, with moving-head inkjet, it is quite rare that the ink is fully cured in just one pass. The image is built up by the printheads scanning back and forth, allowing the curing of that ink image by an energy cumulative effect. For example, a typical ink might require 200 mJ/cm^2 energy density to achieve full cure, then this could be achieved by one pass with a UV source and speed combination resulting in energy of 200 mJ/cm^2 or by four passes with a UV source and speed combination, giving only 50 mJ/cm^2 with each pass. More often than not the latter method is preferable to avoid placing too much thermal energy into the media as a result of the multiple pass modes needed to build up the image resolution (dpi), meaning that the lamp(s) might scan over the same section of the media several times.

An interesting observation of this cumulative cure approach is also that UV peak irradiance (W/cm^2) does not play as important a role as total energy density (Σ mJ/cm^2). Put more simply: sharper lamp focus typically does not lead to a more efficient cure reaction. This is due to the relatively low pigment loading and lower opacity of UV-inkjet inks (even when jetted to give a wet deposit of between 8µm - 12µm) and the fact that the image is being cured layer by layer as it is built up.

Three types of UV bulbs are commonly used "H," "D" or "A" with bulb selection dependent upon the ink formulation. Thus, the UV-inkjet lamp unit must be capable of readily switching

FIGURE 4

Uni-directional, bi-directional and alternative lamp configurations for UV-inkjet systems



between straight mercury and halide-additive bulbs. The "A" bulb is a hybrid halide specially developed for inkjet applications, which gives excellent through curing of deep-ink films via the strong broadband UV output centered around 365 nm while maintaining good UVC for surface closure. However, matching the bulb spectrum and lamp power to an ink and print mode can prove to be a delicate balance compared to many other applications, requiring expertise and experience.

The Role of Printer Architecture in Determining Lamp Configuration

The basic printer design will determine where and how many UV lamps must be integrated into the print engine. Assuming that the print carriage moves back and forth in the "X" axis above the media and the media is moved in the "Y" axis, there are two basic print modes:

- **Uni-directional.** The ink is only jetted and cured when the carriage moves in one direction, the carriage returning to its start position before commencing another print sweep.
- **Bi-directional.** Printing occurs in both "X" axis movements of the print carriage. In Figure 4, the uni-directional printing will normally require only one lamp positioned after the printheads, whereas bi-directional printing requires two lamps to give consistent curing.

An alternative example of a bi-directional configuration is shown in Figure 4 wherein one lamp is positioned between two printhead arrays. However, since this configuration requires double the quantity of printheads, which cost more than UV-lamp units, it is not economically viable.

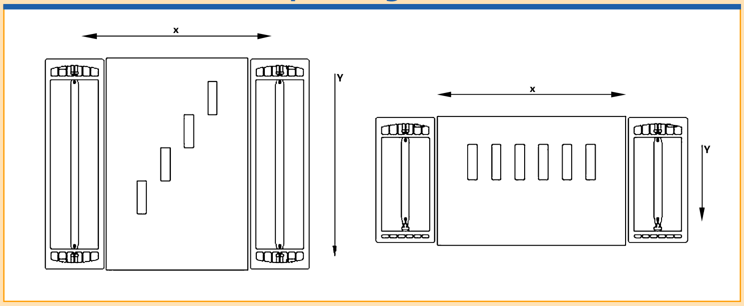
Figure 5 shows a photograph of a bi-directional printer where the lamp units are clearly visible on either side of the printheads.

FIGURE 5

Bi-directional printer with lamps on both sides of the printhead

FIGURE 6

Two alternative lamp configurations



The lamp length is determined both by the formation (or array) of the assembled printheads, and also by the maximum movement of the media in the Y axis (or resolution/ pass mode). In some platforms, all the printheads are mounted in a straight line, while in others they may be stepped to lay down one or more colors at a time.

Figure 6 shows two alternative configurations. The UV lamp must, at the very least, span the full width (swathe) over which ink is being jetted. However, this assumes that the lamp output is sufficient to fully cure the last colors laid down, which may indeed be the case. It is, however, more usual to add to the overall swathe length by the equivalent of "1 x maximum Y step" and to specify the bulb length accordingly to ensure full curing of the last colors matched with optimum power usage.

Third Generation Inkjet Lamp Systems?

In an industry that moves with a frantic technological pace, second generation products have yet to be fully utilized in commercial platforms and yet the protagonists are already asking what comes next? Will it be UV LEDs or laser technology? Probably neither? Both generation one and two UV-inkjet lamp units have several years of life and refinement yet to run, during which time print speeds will doubtless again double or triple.

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