UV Lamp Design for Moving Print-head Inkjet Applications

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Abstract

With the advent of Piezo 'drop on demand' print-heads and the development of "jet-able" UV curable ink systems, the past 5 years has seen a dramatic uptake in the marketplace of UV inkjet. This growth has, (and continues to be), in both static and moving print-head applications. Visit any current graphics show and examples abound with modern roll to roll or flatbed scanning printers producing; banners; POP displays; printing onto glass, wood, & ceramics; as well as static high speed addressing systems; identity and security card printing; and CD printers.

So was this an easy transition for UV lamp technologies to take from offset, screen, flexographic or any other traditional application?

Certainly ink developments in the laboratory were all carried out using known lamp designs, however these did not always translate to the practical machine. Static applications have been able to fairly readily adopt existing UV lamp system technologies (suitably adjusted for the process requirements) however the moving head X-Y plotters/ grand format industrial graphic printers initially struggled to find appropriate lamp units, mainly due to problems of weight and size but also because of other unique requirements.

The Unique Requirement for UV Lamp Units in Moving Head Print-Head Applications

A typical large-scale industrial platform (maybe 60 to 100 inches wide) is not dissimilar in operational principle to a desktop printer, where the media is fed through beneath an array of print-heads that scan from side to side building up the image

The nature of the jetting process using drops as small as 5 picolitres (pL), requires the UV inkjet ink to be extremely low in viscosity to flow readily at the operating temperature of the print head. Therefore to protect the integrity of the image and to avoid colours from merging or dots from flowing and growing, the ink droplets need to be frozen or cured immediately after printing. This dictates that the UV lamps must be placed as close as possible alongside the print heads 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 lamp-head with the print-heads means that size and weight are an issue. Modern printers accelerate the print-heads to speeds in excess of 80 inches/sec (2 m/sec). Heavy and bulky traditional UV lamp-heads place far too great a strain on the servo drive mechanisms, (or require costly up-rated servos). A critical point considering that print quality relies heavily on the accuracy of the servo drive mechanism, and the lighter the overall weight of the print engine the easier this is to achieve.

So a moving head printer needs a small lightweight lamp unit which can still give the same UV output as the traditional large lamp units. But what else? Shuttling the lamp unit(s) back and forth at high speed also subjects it to some new and hitherto irrelevant phenomena:

Firstly; the lamp unit is connected to its associated power supply via an 'umbilical cord', which is going to flex back and forth many millions of times in the power chain, this therefore must be in made out of a suitably rated "hi-flex" type cable in order to avoid premature fracturing or failure. Since certain types of UV run with high voltage or high current cabling, it is not always possible to obtain suitably rated 'hi-flex' cables

Secondly; constant shuttling means that the lamp units also need to 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.

Thirdly; Piezo inkjet print-heads in particular are notoriously sensitive to external electrical noise due to their high firing frequency and rate of data transfer (which can be 10 –20 Khz). With the UV cabling most often running parallel to the print-head signal cables and the UV lamp units mounted immediately alongside the print-heads like a pair of headphones, great care must be taken to eliminate electrical RF interference.

Fourthly; The UV lamp units scan the printed inks at a height above the media of less than 0.2" (5mm) and at speeds of up to 100 inches per second (2.5 m/sec), thus air flow from the lamp cooling could readily disrupt the drop pattern of the inks. Therefore it has proven necessary to have isolated air systems – typically in the form of a quartz exposure window – in order to seal off the curing zone. This also places physical restrictions on the design of the internal lamp cooling. Since most lamp units use air cooling of one form or another, it is also preferable to include some form of self-contained cooling systems within the lamp unit itself so as to eliminate hoses or ducts trailing across the machine.

All of these points taken in combination have led to the development of highly compact lightweight UV lamp units specifically designed for integration into moving head UV inkjet platforms. Initial market success was in the wide format graphics markets, however as UV inkjet has gained ever wider market acceptance, we have seen it's adoption on smaller and more office based products, This has rapidly led to the development of a second generation of UV lamp units for ink-jet which are even smaller than the first generation, and more importantly comply with IT based standards requirements such as UL 60950 so as to be suitable for office and commercial shop based environments. Previously ink-jet UV systems only met approvals for industrial applications, and this latest generation of UV ink-jet lamps has led to some interesting adoption of novel constructional materials in UV systems such as high temperature automotive composites, carbon fibre, titanium and ceramics.

The Need for High Speed Light Shutters

One of the biggest problems encountered by the new generation UV flatbed printers is that of UV light reflecting back into print-heads from the media or machine parts, which irreparably damages them. Print-heads are the single most expensive set of components in a printer. When printing onto thin materials the low scanning height of the lamps does not normally allow sufficient angle of incidence for UV light to reflect back into the print-heads.

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.

Print-head damage (nozzle blocking) can occur even with very small doses 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 unit(s) is 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.

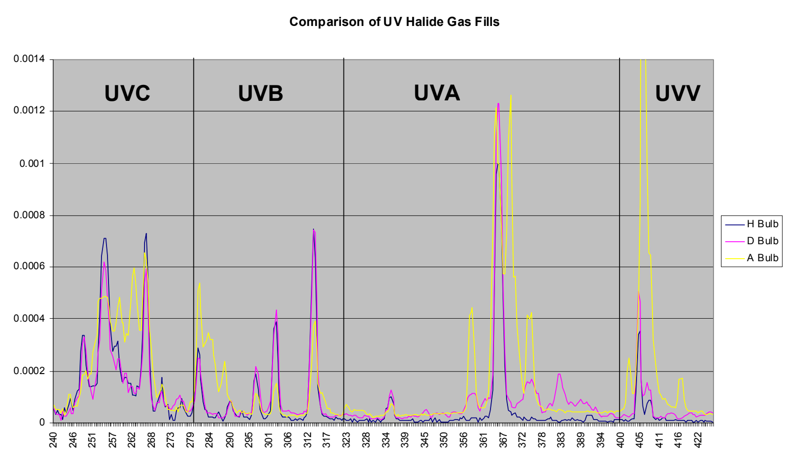
Shutters for UV lamp units are, of course, nothing new. Traditional lamp shutters open when printing commences and close when printing stops. However, on an inkjet platform the shutters may cycle every 2 seconds or less which means that on average they would be subjected to a duty cycle 300 to 500 times more rigorous than for example on 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 100ms with very low inertia while being subjected to 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.

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 print-heads scanning back and forth, allowing the curing of that ink image by a cumulative effect. For example, a typical ink might require 200mJ/cm^2 energy density to achieve full cure, then this could be achieved by one pass under a light source with an energy density of 200mJ/cm^2, or by 4 passes beneath a light source giving only 50mJ/cm^2. More often than not the latter method is preferable to avoid placing too high an amount of thermal energy into the media as a result of the multiple pass modes needed to build up the image resolution (d.p.i.), meaning that the lamp(s) might scan over the same section of the media several times.

An interesting observation of this cumulative curing approach is also that UV peak irradiance (w/cm$^{\wedge 2}$) does not play as important a role as does total energy density (Σ mJ/cm^2). Put more simply: with UV ink-jet a sharper lamp focus typically does not always 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 8um – 12um), and the fact that the image is being cured layer by layer as it is built up.

Primarily three types of UV bulbs are commonly used, H, D, and A, with bulb selection dependent upon the ink formulation. Thus, the UV inkjet lamp unit must be capable of readily switching between straight mercury and halide-doped 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 centred on 365nm, while maintaining good UVC for surface closure. However matching the bulb spectrum and lamp power to an ink and print mode can prove quite a delicate balance compared to many other applications, requiring expertise and experience. The chart below illustrates the spectral differences between these bulbs:



The Role of Printer Architecture in Determining Lamp Configuration

The basic design of the printer 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, then there are two basic print modes: a) unidirectional printing where 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, and; b) bi-directional where printing occurs in both 'x' axis movements of the print carriage. Unidirectional printing will only normally require 1 lamp positioned after the print heads, whereas bi-directional printing will require 2 lamps to give consistent curing.

An alternative example of a bi-directional configuration is wherein one lamp is positioned between two print head arrays. However, since this configuration requires double the quantity of print heads - which cost more than UV lamp units - it is not normally economically viable.

The lamp length is determined both by the formation (or array) into which the print-heads are assembled, and also by the maximum movement of the media in the Y axis (or resolution/ pass mode). In some platforms all the print-heads are mounted in a straight line, while in others they may be stepped to lay down one or more colours at a time. 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 colours laid down in one pass, 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 in order to ensure full curing of the last colours matched with optimum power usage.

Future Directions?

As part of a continued attempt to reduce the overall energy used in UV ink-jet platforms, recent work has centered around the "pinning" or "freezing" of inks. This process involves low output lamps or UV sources positioned in the usual way, however emitting just sufficient energy to "pin" or "freeze" the ink droplet after jetting, stabilizing it and arresting any drop spread. Typically the whole image is then built up in this fashion before a full cure is effected as a second phase using a normal lamp.

This work has seen the introduction of UV emitting LED's used effectively for the first time. UV LED's at the time of writing are still early in development, and emit relatively small amounts of energy (and always at a discreet wavelength). The LED's need to be packed into dense arrays of typically around 110 chips per square cm in order to achieve a usable intensity, and at present require specially formulated inks. However the writer is confident that early advances will be seen in the use of this aspect of UV technology.

Notwithstanding new developments such as LED's, the ever increasing speeds of existing printers and market "down-costing" as this technology matures, continues to fuel the development of arc based UV ink-jet lamp units. Certainly we can still expect to see these products for some years to come in an evolution cycle ever miniaturized yet maximizing performance.

Author Biography

Adrian Lockwood graduated with honours from the University of Manchester in 1977, working firstly with Wallace Knight & Colordry, which later became the Spectral Technology Group, and Nordson UV from 1996.

A co-founder of Integration Technology in 2000, he is also a Fellow of the Royal Society and an Associate of the Institute of Packaging. With over 25 years experience in the UV curing industry, he has authored many technical papers and is a frequent speaker at international conferences.