Meeting the Challenges of UV Ink Jetting in Wide Format Applications

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Abstract

In their desire to exploit new markets, an increasing number of wide format and super-wide format printer manufacturers have embraced UV curable inks, particularly for flat bed architectures. From a printhead manufacturer's perspective, the migration from aggressive, fast-drying solvents to less aggressive, non-drying UV acrylates was expected to increase printhead reliability and extend service life. The reality, however, is far more complex, as UV curable inks bring their own unique set of maintenance issues. This picture is further complicated by the fact that UV ink problems are more likely to result in permanent printhead failures. This paper addresses the root issues of UV ink jetting difficulties, outlines ink handling and printhead maintenance strategies to overcome these vulnerabilities, and describes the cooperative relationship needed among printer equipment manufacturers, ink suppliers, and printhead providers to implement a successful UV ink printer program.

Introduction

UV curable inks are enjoying increasing popularity in wide format and super-wide format printing applications because of their ability to adhere to a wide range of substrates and their superior film forming properties. This has been especially true with the proliferation of flat bed architectures, as the wetting characteristics of rigid substrates are more demanding than the flexible materials used in roll-to-roll printers. Ironically, it is the same properties of UV curable inks that make the inks so desirable for wide format applications – permanent cross-linked films and chemical inertness – that can turn common ink handling mistakes and printhead maintenance lapses into irreparable ink jet printhead failures. Thus the key to enjoying a long printhead service life in UV ink applications is to implement the appropriate maintenance procedures and system safeguards to prevent premature cross-linking/curing of the ink within the printhead.

Radical Cure UV Ink Properties

Before discussing specific maintenance procedures, it is important to have a good understanding of the inherent ink characteristics. A typical radical cure UV ink formulation includes a viscosity-balanced mixture of acrylate monomers and oligomers, a "package" of photo initiators, surfactants (to improve wetting of difficult substrates), color pigments, pigment dispersants, and cross-linking inhibitors. UV curable inks are by their very nature reactive materials. Free radicals occur spontaneously and the presence of inhibitors is necessary to prevent the formation of a point cure. This explains the non-intuitive circumstance that inhibitors are being added to ink when, at the same time, printer manufacturers are demanding a reduction in the total amount of UV light energy needed to fully cure inks. However, realistically inhibitors can only do so much. The rate of spontaneous free radical occurrence increases with temperature. Consequently excessive heat is a concern when handling UV inks. Also the affect of these free radicals accumulates over time. Hence UV curable inks have a finite shelf life. Finally, some materials, notably copper, act as a catalyst and must not be in contact with the ink. Because of these reactive characteristics, even the most benign radical cure UV ink formulation requires special attention in comparison to the pigmented solvent ink commonly used in the wide format industry today.

Unfortunately, the continued demand for lower cure energy, better substrate adhesion, and improved film abrasion resistance has led ink manufacturers to increase the reactivity of the UV curable inks. One of the most commonly used photo initiator for fast curing inks today also has some sensitivity to wavelengths in the visible range. So while UV energy is easy to block, inadequately shielded ambient lighting can increase the likelihood of curing upstream of the printhead. Since oxygen is a well-known curing inhibitor (hence the use of nitrogen blankets to promote faster curing in some implementations), ink manufacturers have chosen to increase their reliance on the presence of oxygen in order to reduce the amount of other inhibitors in their formulations. Generally, this has minimal effect of the storage/shelf life of the ink. However, the inline degassing used within some printheads to increase high frequency jetting performance also reduces the oxygen content of the ink. This effectively increases the reactivity of the ink – with the potential for causing maintenance issues downstream at the nozzle.

The ink jet nozzle is also vulnerable to the use of volatile components within the ink. Although UV curable ink is touted as being "100% solids", in actual practice, the faster curing formulations exhibit a "de-cap" phenomenon caused by evaporation of the lower molecular weight components in the formulation. This means that when left idle for a period of time, the nozzle may not start jetting immediately again without a maintenance procedure, or in extreme cases, is never recoverable. Thus the need to manage the ink at the meniscus increases the maintenance requirements for the printer equipment manufacturer.

Ink Handling Requirements

Ink jet inks intended for the graphic arts market are typically filtered to a sub-micron level during manufacture. Nonetheless, it is important that these inks are passed through a high capacity filter, typically in the 8 to 10 micron range, before introduction into a printhead, to capture any gels that may have formed during shipping and storage. A large filter surface area is required to prevent a high pressure drop resulting from a loaded up filter, which could be sufficient to extrude gelatinous substances through the mesh intact. Ink manufacturers generally specify the allowable storage temperature range and maximum shelf life to ensure that the formation of any gels is kept to a minimum.

In addition to filtering the ink upstream of the printhead, the printer manufacturer should ensure that all materials used in the ink supply system are fully compatible with the ink and that every component is sufficiently opaque to both UV and visible light.

Printhead Maintenance Strategies

Most printhead maintenance concerns involve managing the ink at the nozzle and/or nozzle plate. An obvious, yet commonly under addressed consideration, is the shielding of the printhead face from stray UV radiation. UV lamps in usage today emit a tremendous amount of UV energy. Adequate intensity is needed to ensure full cure for up to three layers of ink, and the overall lamp power has increased as printhead throw rate and carriage speeds have increased. The difficulty in shielding stray radiation is further complicated by the fact that UV lamps are often packed as close to the printheads as possible to minimize the overall carriage size. The strategy for protecting the printhead is to ensure that there are no possible angles where reflected/scattered light from the lamps will reach the nozzle plate. Equally important is what happens when the carriage is off the media. The larger distance from the lamp to the table bed or other exposed machinery components increases the likelihood that reflected light will find a path back to the nozzle plate. Thus the use of a lamp shutter and/or UV absorbent coatings on exposed surfaces is essential to prevent light scattering during carriage reversals.

While it may appear to a printer manufacturer that it takes a tremendous amount of UV light to achieve the full cure required for good adhesion and scratch resistance, relatively little UV intensity is necessary before problems can begin to occur at the nozzle plate. Whether using a “wetted” or “non-wetted” nozzle plate technology, the accumulation of satellites means that there is always a slight film of UV ink present on the nozzle plate. If exposed to stray UV radiation and not periodically removed, this film will begin to increase in viscosity. Given enough accumulated dosage, a tough enamel-like film will eventually be formed. Should the ink begin to cure close to or within the nozzles, jetting problems can develop, generally in the form of misdirected or weakened jets. Even partially cured ink distant from the nozzles can become a hazard, as it can be smeared into the nozzles during a maintenance wiping procedure.

The appropriate protocol for preventing jetting problems due to cured ink in the nozzles has two elements. First, the development of thickened ink on the nozzle plate should be prevented as much as possible through the shielding of stray UV radiation, as described above. Second, the film of ink on the nozzle plate should be managed properly. Common maintenance techniques, like printhead purge and wipe procedures, should be applied frequently to present a fresh pool of ink in and around the nozzles. Further, the nozzle plate should be thoroughly cleaned on a periodic basis to remove any partially cured ink. Just like one would not use a dry towel to wipe spilled honey off a surface, a suitable solvent should be used to improve efficacy of the periodic cleaning. This solvent needs to be both miscible with the ink as well as compatible with the printhead construction materials. While it is unlikely that a compatible solvent will dissolve a UV ink that is fully cross-linked, it can help disperse partially cured gels before they reach a consistency that would permanently block a nozzle.

There are other considerations for printhead maintenance. A variety of techniques have been employed by solvent printer manufacturers to prevent the drying of ink in the nozzle. The use of periodic jetting or purging while idle can be used in a similar manner to overcome the “de-cap” phenomenon that occurs with some of the fast curing UV inks. For longer periods or for very volatile inks, the printhead should be flushed out with an appropriate solvent to prevent irrecoverable curing/drying in the nozzles.

Another factor may affect printhead life. Many printheads feature an internal filter screen. While this element works effectively to prevent the occasional particle from reaching the nozzle, the low velocity/pressure drop across the screen makes it an ideal catcher for partially cured ink gels. If enough accumulate, they can begin to weaken the performance of an individual channel. The only recourse for this tendency is to ensure that no conditions exist that allow the formation of gels between the primary filter and the internal filter screen.

A Three-Way Partnership

The challenges of maintaining UV curable inks require a three-way collaboration among printer equipment manufacturers, ink suppliers, and printhead providers. Ink formulators need to carefully balance the stability of the ink during shipping, storage, and operation with both the UV cure energy requirements and the final properties of the jetted ink on the substrate. Each ink formulation needs to be fully compatible with the targeted printhead construction materials. Further, the ink supplier must work with the printhead manufacturer to identify a solvent cleaner that is compatible with the printhead and is an effective cleaning agent for the partially cured ink, as well as qualifying a flush/packing fluid for extended shut down periods. The printer manufacturer and the ink provider must collaborate to ensure that all the ink supply components are compatible with the ink and adequately opaque to the sensitive wavelengths of the photo initiators. The ink shipping and storage restrictions, both within the bottle and within the printhead, need to be determined and effectively communicated to prevent any irreversible deterioration in the printhead performance. Lastly, all three parties need to cooperate to implement an effective suite of maintenance procedures to manage the ink film at the nozzle and printhead face.

Conclusion

UV curable inks offer superb characteristics for demanding wide format applications. However, these inks present unique challenges to printer builders, as their inherent reactivity can lead to permanent printhead failures. Through the awareness of the critical UV ink properties, a coordinated approach by printer equipment manufacturers, ink suppliers, and printhead providers can implement the necessary maintenance protocols to ensure an acceptable service life.

Biography

Marc K. Torrey holds a BS in Mechanical Engineering from Rensselaer Polytechnic Institute in Troy, NY and a Masters degree from Lesley College in Cambridge, MA. He is a former employee of NASA and Boeing, and has a strong background in real-time embedded control systems.

Marc has worked for Spectra for the past 18 years with piezo ink jet printheads, acquiring extensive experience in printhead design and prototype fabrication, system integration, and engineering consulting for a broad range of high-performance industrial printing applications. Marc is based in Amsterdam, where he has managed Spectra's sales and technical support activities in Europe and the Middle East for the past three years.