EB Curable Flexographic Inks for Flexible Packaging

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ABSTRACT

EB curable flexographic inks have recently been introduced to the flexible packaging market. The new EB ink system offers the benefits of UV curable inks—like good print quality, high gloss and product resistance—while eliminating needs in interstation curing. The system has an efficient cure response that allows for complete cure with low voltage electron beam systems. EB curable flexo inks will offer reduced ink consumption during the printing process.

INTRODUCTION

Today, electron beam technology is aggressively penetrating the flexible packaging market. Several new applications recently introduced to the market include high gloss coatings that replace lamination; cold seal release coatings, and lamination adhesives. EB curable inks are the missing part that would complete the "package" of products required for decoration of most of the flexible packages.
Such a system has been recently developed and is currently being introduced on the flexible packaging market.

UV FLEXO LESSONS

UV flexo technology was first introduced to the packaging market by Kobush in the early 90s, suggesting some revolutionary changes in packaging printing. It was immediately noticeable that UV flexo inks offer outstanding quality of the gray scale reproduction, well defined dot structure with minimum gain during the printing process, high gloss, and outstanding product resistance properties[1]. While, this highly publicized project ended a few years after its initial introduction, UV flexo printing remains the fastest growing segment of printing technology. Most of the applications of UV flexo are in the areas of label(ing?), outdoor bag, and folding carton printing.

Food packaging, the largest segment of the converting industry, is still mostly closed to UV flexo printing. There are two major reasons for this: First, the odor of the cured UV flexo inks remains objectionable to many converters. Second, press speed is still limited to 150-200 m/min—a result of deficiencies in the cure of the dark colors that compete for UV light with photoinitiators. The excess of IR generated by UV lamps requires substantial modifications to the design of the CI (central impression) press; specifically, to improve heat management. This increases both the cost of the press and its maintenance.

WET TRAPPABLE EB FLEXO INKS

Understandably, the development of EB curable flexo inks has focused on elimination of inherent deficiencies limiting UV flexo growth. EC curable inks would have to abolish the need in inter-station curing, increase printing speed, and significantly reduce odor of the cured ink film. The key requirement in introduction of EB curable liquid inks is the elimination of inter-station drying, or curing. It is simply impossible to introduce inter-station EB curing to CI press, the design that dominates printing on flexible packaging .

The wet trapping of EB flexo inks has been accomplished with the design of an ink system that can undergo an instantaneous transition from the liquid to the semi-solid state upon transfer from the anilox onto the printed substrate. This transition allows (what?) to trap consecutive ink layers on the top of each other without using any source of energy (drying or curing).

This scheme is a general concept of the wet trapping that can be used for a multi-color flexographic printing and consecutive curing under EB irradiation without generating heat, as required for the additional cooling of CI drum. The EB curable inks are photoinitiator free, which makes them much more suitable for food packaging. This process can be used in surface printing and combined with overprint coatings and lamination adhesives.

PERFORMANCE ATTRIBUTES OF EB FLEXO INKS VS. EXISTING TECHNOLOGIES

The potential "targets" of EB flexo are solvent and water-based ink technologies. While all these inks are designed for the flexographic printing, physically, they are significantly different. Press ready water and solvent based inks typically don't contain more than 40-45% solid components, including pigment, film forming resins, and additives. Their viscosity ranges from 50 to 70 cps at about 100 s^{-1}/25C^{o} shear rate, and requires inter-station drying for multicolor printing. This drying limits speed – without the sufficient removal of water and solvent, acceptable trapping of individual colors cannot be achieved.

The low viscosity of these inks is detrimental to both the process print quality and the fidelity of the printed image. Low viscosity inks tend to spread on the printed surface, causing excessive dot gain in the highlights of the image (below 20% dot area) and filling in the dark tone areas (over 75%). It is very difficult, if at all possible, to produce robust solvent or water based inks with a higher viscosity that would have less spreading on the printed surface, as required for a better fidelity of the printed image. Higher viscosity inks require a higher concentration of solids, which usually lead to a poor press stability (excessive drying on plate and anilox, limited re-wetting).

UV an EB flexo inks are much higher in viscosity, typically in the ranging frrom 300 to 1000 cps at 100 s^{-1} shear rate, 25C^{o}. This leads to exceptionally good reproduction of the process dots in all the gray scale regions. It is not uncommon for commercial UV flexo printers to print 1% and 2% dots, while keeping open 95% and even 98% dot areas. Since no drying takes place, UV ink's press stability is not affected by higher viscosity. Similar print quality has already been achieved with EB flexo inks.

COMPARATIVE STUDY OF THE PRESS PERFORMANCE AND INK CONSUMPTION

A transition to EB curable flexo inks requires a capital investment in EB curing equipment. This decision should be based on the comparison of the comprehensive cost and performance analysis of the new technology to the existing solvent and water based ink technologies. An ink press performance is an important element of the transitional model. Thus, the testing of all three ink systems on the same press with the same application conditions is important to the understanding of potential benefits and deficiencies of the new process.

A printing study was undertaken on the 14" wide Chesnut flexo press equipped with dryers for conventional inks and ESI EB unit. Banded anilox roller (Appendix - Table 1) was used to simulate four different engravings typically used to print process and line colors. The goals of this study were to estimate total ink consumption with different anilox roller, and also to determine the print density and gloss that could be achieved with each ink system. The cyan color was selected for all ink systems. The inks were printed on the same; corona treated in line polyethylene/polystyrene blend film via solid photopolymer plate. Both water and solvent-based inks were adjusted to the press ready viscosity of about 30 sec/Zahn#2 cup. Percent solids for both conventional inks were 42% and 38% respectively.

As Graph 1 indicates, total applied weight of conventional inks is substantially higher than it is for EB flexo inks, especially for the low volume anilox engravings. The consumption of both conventional inks is about 33% higher than EB ink at 250 lpi anilox count. With lower volume anilox, this difference is lower, but is still around 23 %. Since EB chemistry is more expensive than conventional systems, it is highly recommended to always attempt the printing with the lowest anilox volume possible. If this is done, a converter will be able to reduce the total ink consumption while achieving higher print quality.

While the total (wet) applied film weight is lower for EB inks, it is higher than the dry weight of both water and solvent based inks (Graph 2), leading to much higher print density (Graph 3) and gloss (Graph 4) of EB inks with within entire range of anilox volumes. EB cyan ink has much 45 - 65 % higher density and much higher gloss than water and solvent cyan inks.

Using density data, we can calculate the theoretical anilox requirements needed to achieve the target of 1.43 process print density for the cyan ink. In order to get 1.43 print density on corona treated PE film, we would have to use 566 lpi, 604 lpi and 751 lpi anilox rollers for water based, solvent based and EB curable inks respectively (Graph 5). In terms of the ink consumption, we would have to use about 34% more of conventional inks than EB ink (Graph 6). Obviously, this is just an indicator of the trend. Actual anilox selection depends on cell volume, depth to opening ratio and some other factors.

CURE AND PHYSICAL PROPERTIES OF THE CURED EB FLEXO INKS

One of the benefits of EB curing is that the total energy delivered to a printed image is constant in a broad range of press speeds. This—along with the fact that, unlike UV curing, there is a little interference from the pigments—helps us design an ink system that would offer a constant performance in a broad interval of the press speeds. On Graph 7, we can see that at the dose below 2 Mrad, cured ink films, while completely dry, show limited chemical resistance. As soon as the cure dose reaches 2 Mrads or higher, chemical resistance of the cured film increases significantly, which is usually an indication of improved mechanical and resistance properties.

Difference in a number of alcohol rubs between colors does not contradict the previous statement that most pigments do not interfere with EB cure. This just points to the fact that color density targets are different for individual inks in the process printing, Target densities are produced with a different amount of pigment in the ink composition that affect polymer network formation during polymerization and free volume of the cured film. Higher free volume usually allows for faster permeation of solvent through the cured film and reduced rub numbers.

Initial laboratory and field testing shows that physical properties of EB inks cured at 2-3 Mrad of EB dose to 15-30 Alcohol rubs are much better than typical resistance properties of conventional inks. Tightly cross-linked EB flexo inks offer a very broad performance window that should be able to satisfy many end use requirements.

CONCLUSION

EB curable flexographic inks offer to the flexible packaging and converting market a new process that is free from the deficiencies of UV flexo printing, yet superior in print quality and physical properties of the finished package to conventional water- and solvent based ink technologies. The total cost of such a transition still needs to be evaluated, but it is expected that consumption of EB inks will be lower than it is for conventional inks.

ACKNOWLEDGMENTS

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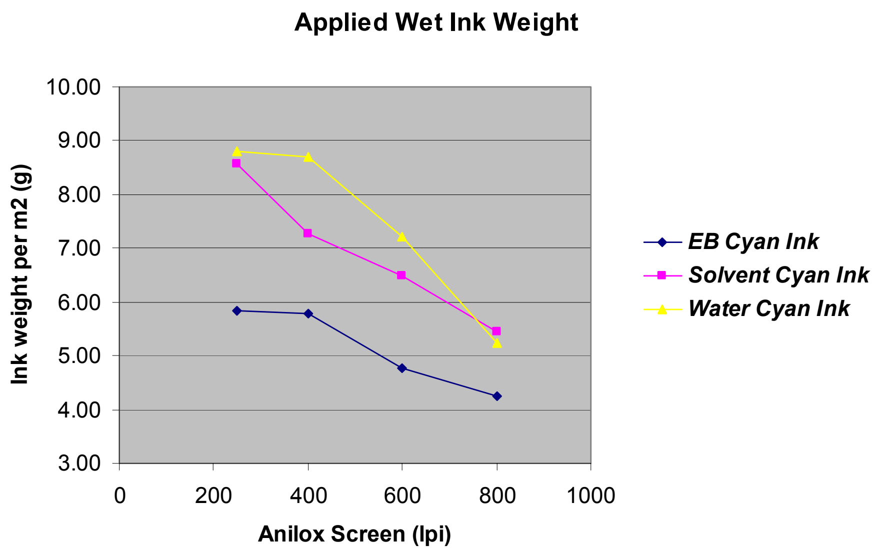
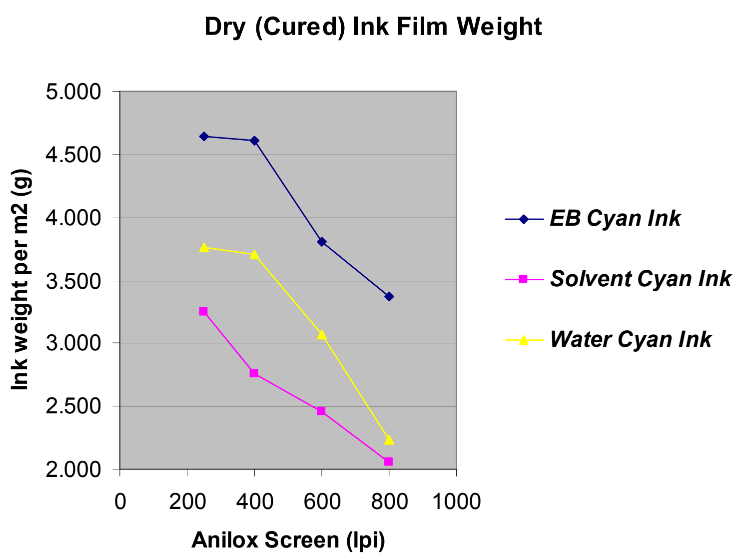
REFERENCES

Gerog Bolte. UV Printing on Thin Films., RadTech Europe, Website – June 03, Paper of the Month, www.radtech.europe.com/boltepagejune.html

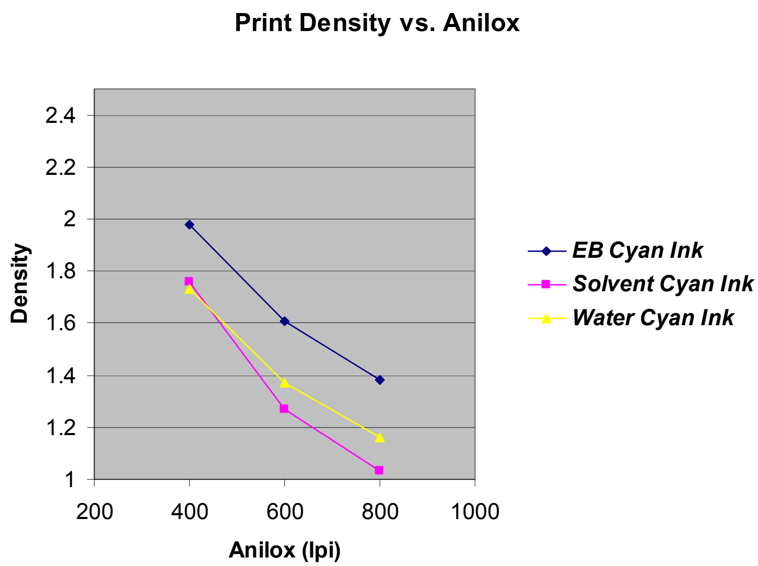
APPENDIX



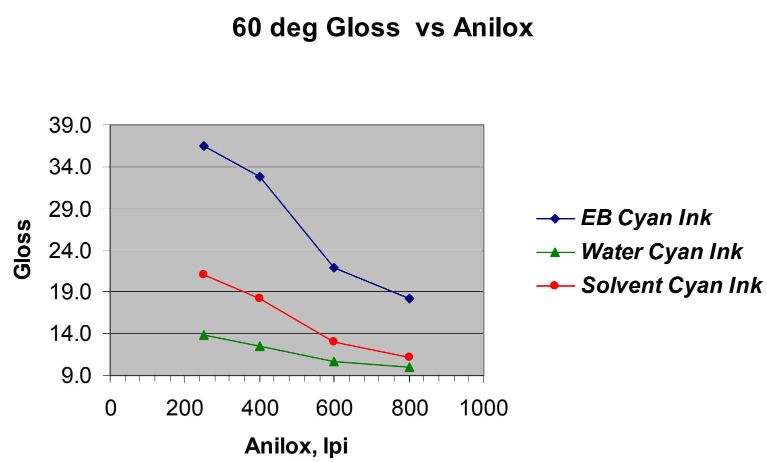
Graph 1 ***Applied (wet) film weight of EB, solvent and water based cyan inks with different volume of anilox engravings.***
Test conditions: 14" Chesnut flex press, Cyrel photopolymer plate, 100 fpm press speed; EB – ESI 125 kV, 3 Mrad; 200 ppm O_2.



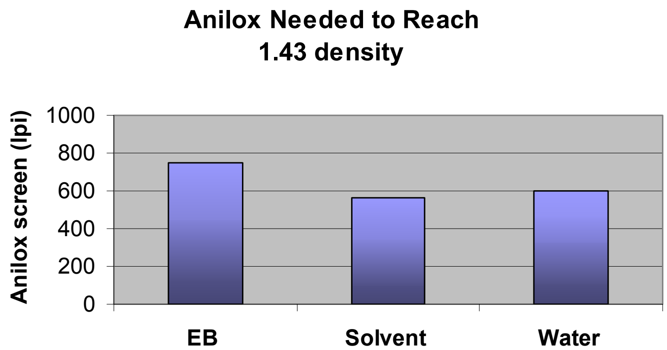
Graph 2 ***Applied dry film weight of EB, solvent and water based cyan inks with different volume of anilox engravings.***



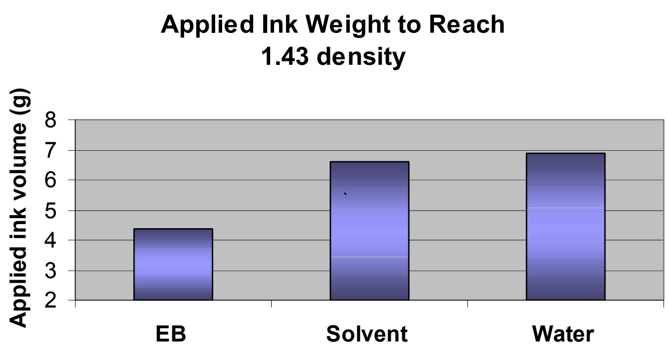
Graph 3 ***Print density of EB, solvent and water based cyan inks with different volume of anilox engravings.***



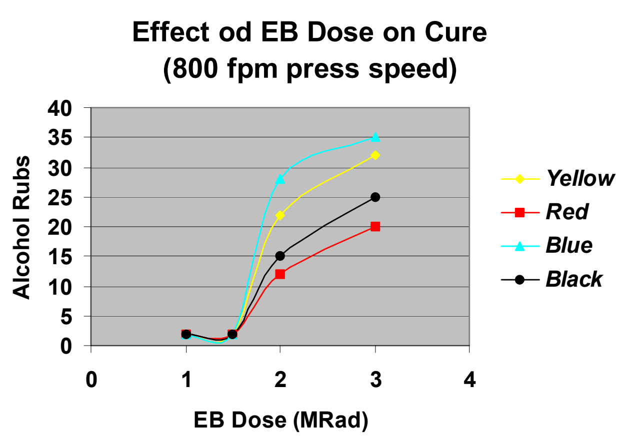
Graph 4 ***Gloss of EB, solvent and water based cyan inks with different volume of anilox engravings.***



Graph 5 *Calculated znilox requirements for EB, solvent and water based cyan inks to reach 1.43 print density. b*



Graph 6 *Calculated consumption of EB, solvent and water based cyan inks to reach 1.43 print density.*



Graph 7 *Cure of EB yellow, red, blue and black ins under different EB dose exposure at 800 fpm CI press speed*

Table 1 Banded anilox roller for Chesnut press

250 lpi	400 lpi	600 lpi	800 lpi
5.8 bcm	3.7 bcm	2.5 bcm	1.8 bcm