New Generation Binder for UV Offset Inks

Abstract:

UV-radiation curing is a well accepted technology in the graphic industry. The transformation of the liquid ink to a cured solid takes place within a fraction of a second on UV illumination at ambient temperature. In commercial sheetfed printing, UV inks have enabled printers to increase productivity and improve characteristics such as gloss and resistance properties.
Although an established technology, differences still exist in the runnability on the press of UV versus conventional lithographic inks. UV inks still seem to have less latitude in ink water balance. Development of a new binder has resulted in UV lithographic inks with more stable ink water emulsion, closing the gap with conventional oil based inks.

Introduction:

UV-radiation curing technology has become well accepted in the graphic industry. Post press productivity is improved due to the immediate drying of UV inks. Press behaviour, however, now needs to be improved. Comparison, in the laboratory, of commercial UV sheet-fed inks with conventional sheet-fed inks has highlighted differences. Ink properties such as rheology, tack, misting, colour strenght, ink water balance and cure speed were examined.

Ink water balance was evaluated using a lithotronic.
Basically, the Lithotronic measures the change in viscosity (torque) of an ink when water is emulsified in it. The type of ink water emulsion formed has a large impact on the press behaviour and the print quality result. Ideally, when water is emulsified in the ink, the viscosity should only under go a minor increase. This ensures a good ink transfer on the press (Type B – fig.1). If the emulsion is too fine and too stable, it will lead to a loss of density and possible ink build up (Type A – fig.1). If the emulsion is too coarse (Type C – fig.1), it can lead to unstable press behaviour making regular press control necessary.

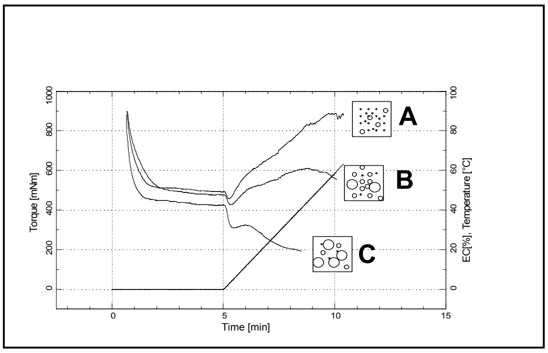


Fig. 1: *different types of ink water emulsion, measured on lithotronic*

“C” curves are typical of UV inks, while “B” curves are typical of conventional inks. It is thus essential to improve the ink water balance (type of emulsion) of the UV inks. An ink water emulsion that is more stable will have a positive impact on tack and misting (amongst other characteristics), these two properties need to be improved as press speeds increase. Together with pigment wetting, the above mentioned parameters were the subjects of research programs.

A new high molecular weight polyester acrylate was developped, having an excellent ink water balance. A more stable emulsion ensures good runnability on press due to constant ink transfer, reduced misting and dot gain.

Ink properties: UV v. conventional lithographic inks

In table 1, some lab test results for commercially available UV and conventional sheet-fed inks can be found. These figures were determined during an evaluation of inks coming from 5 different suppliers. This evaluation included inks for paper and board as well as inks for plastics.

The most obvious differences for UV inks are a higher structure (low shear viscosity) and higher tack, especially at higher speeds,. UV inks form a coarser less stable emulsion than conventional inks (see fig.2).
The higher structure can have a negative impact on the ink flow in the ink duct. This structure can be attributed to an inferior pigment wetting of the UV binders and the prescence of fillers used to improve misting.

	UV	Conv.
Visco 0,1s^{-1}@ 25°C	500-1000 Pa.s	100-700 Pa.s
Visco 100 s^{-1} @ 25°C	35-50 Pa.s	30-40 Pa.s
SI	15-30	3-15
Tack 50 m/min	100-200	100-120
Tack 350 m/min	400-700	200-250
Misting 1.0 cc 50°C	0.40-0.60	0.30-0.60
Density – 1,5 g/m²	1.5(Y)-2.1(B)	1.5(Y)-2.1(B)
Gloss – 1,5 g/m² 60°	20-30	20-30
Solvent resist. (ADR)	>50	1-2

Table 1: *lab results for a commercial UV and a sheet-fed inks.*

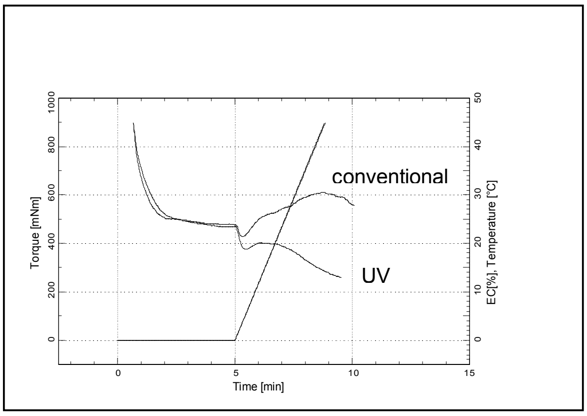


Fig.2: *typical lithotronic curves for a UV and conventional a conventional sheet-fed ink.*

UV Offset ink formulations: state of the art

UV inks for paper and board will mainly contain dimer acid based polyester acrylates for good pigment wetting and good ink water balance. Epoxy acrylates are added to reduce the cost and to increase the cure speed, hardness and scratch resistance. High functionality urethane acrylates are sometimes used in darker colours inks such as cyan and black.

General UV offset ink formulation (paper/board)		
Components	***Content***	***Characteristics***
Polyester acrylates	20-30%	Pigment wetting, ink water balance
Epoxyacrylates	30-50%	Increase reactivity and scratch resistance
High funct. urethaneacrylates	0-10%	Increase reactivity and scratch resistance (Black)
Pigment	14-19%	Colour
Fillers	4-8%	Decrease tack and misting
Wax	1%	Increase scratch resistance and slip
Reactive diluent (GPTA)	0-5%	Viscosity adjustment
Photoinitiator blend	8-12%	Initiate cure
Stabilisors, inhibitors	<1%	Improve shelf live

Table 2: *General UV offset ink formulation for paper and board*

General structures of acrylate oligomers are depicted below.

Fig.3: *Polyester acrylates (PEA):*

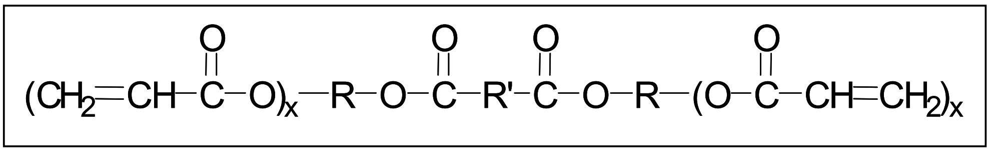
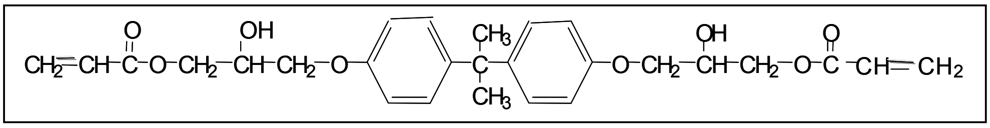
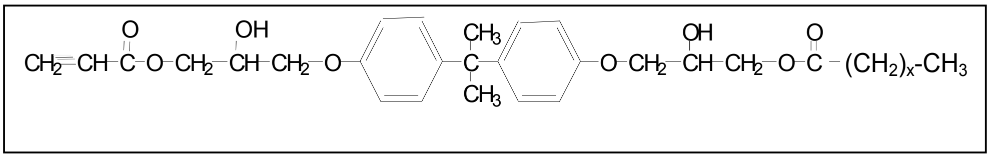


Fig.4: *Bisphenol A diglycidyl ether (BADGE) based epoxyacrylate (EA):*



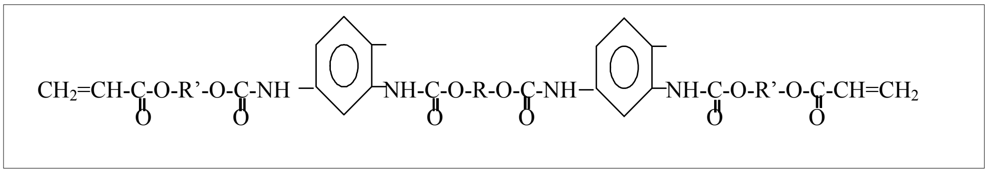
- Properties: hard, solvent and water resistant, fast cure, lower cost.

Fig.5: *Fatty acid modified epoxyacrylate (FA mod EA):*
Part of the acrylic acid is replaced by a fatty acid (saturated or with C=C bonds)



- Properties: compared to standard epoxy acrylates, a fatty acid modification improves pigment wetting and ink water balance. Cure speed is decreased.

Fig.6: *Urethane acrylate (example of a difunctional aromatic UA):*



- Properties: various physical properties from soft and non coherent to hard and tough
  - Aromatic UA : lower in price than aliphatic but yellowing.
  - Aliphatic UA : light fast, expensive!

UV Offset ink formulations: oligomer evaluation

To examine the influence of each component, oligomers (polyester acrylates, epoxy acrylates, urethane acrylates etc...) are first evaluated in a cyan pigment dispersion (formulation see Table 2). The viscosity is adjusted to 30 – 40 Pa.s (25°C) with propoxylated glycerol triacrylate (GPTA).

Components	*Content*
Oligomer	68-x
GPTA	x
Stabilisors, inhibitors	1
Pigment PB15:3	17
Filler	6
Photoinitiator blend	8

Table 2: *Test formulation for evaluating oligomers.*

In table 3 and Fig.7, the results of some commercially oligomers currently used for the production of UV offset inks are shown. Following oligomers are compared:

PEA 1: tetra functional polyester acrylates (x = 2)
PEA 2: hexa functional polyester acrylates (x = 3)
EA: Bisphenol A diglycidyl ether (BADGE) based epoxyacrylate
FA mod EA: Fatty acid modified epoxy acrylate
UA: hexa functional aromatic urethane acrylate

	PEA 1	**PEA2**	**EA**	**FA mod EA**	**UA**
Visco 2,5 s^{-1}@ 25°C (Pa.s)	72	76	67	70	83
Visco 100 s^{-1} @ 25°C (Pa.s)	30	35	33	31	30
Shortness Index	2.4	2.2	2.0	2.2	2.8
Tack 50 m/min – 30°C	200	180	200	220	180
Tack 350 m/min – 30°C	630	520	650	730	650
Misting (1.0 g - 50°C – 350 m/min) - OD	0.40	0.44	0.35	0.46	0.37
Optical Density at 1,5 g/m²	2.05	2.10	1.90	1.95	1.85
Gloss 60° at 1,5 g/m²	23	24	22	23	19
Reactivity @ 120W/cm (m/min)	20	30	150	80	70

Table 3: *Results of cyan dispersion based on different oligomers*

Looking at Fig.3, it's clear that the polyester acrylates have the best emulsion behaviour. Epoxy acrylates and urethane acrylates have a detrimental effect on ink water balance. The fatty acid modification had only a minor effect on the emulsion properties of the epoxy acrylate while noticeably reducing the reactivity (see Table 3).

The cause of the bad ink water balance for epoxy acrylates may be found (partly) in the presence of free hydroxyl groups formed during acrylation of epoxies. For urethane acrylates it is probably the hydrophilicity of the urethane group.

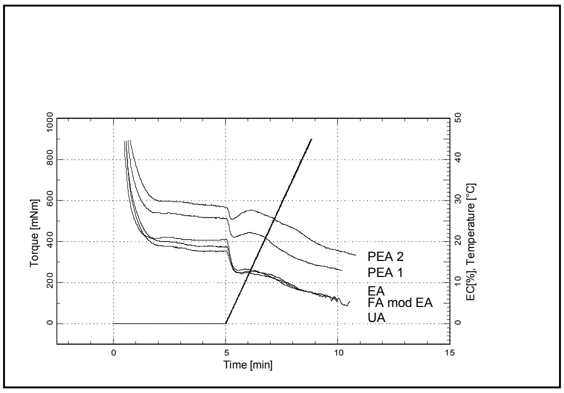


Fig.6: *lithotronic curves of cyan dispersions based on different oligomers*

Different options adressing above mentioned points were investigated. Finally, our R&D efforts were focused on improving the ink water emulsion properties of polyester acrylates.

New generation polyester acrylate

A new polyfunctional polyester acrylate, with a higher molecular weight than that of existing polyester acrylates was developped.

Below, a comparison with PEA 1 using the formulation of Table 2 can be found:

	cyan	
	PEA 1	**New PEA**
Visco 2,5 s^{-1}@ 25°C (Pa.s)	72	61
Visco 100 s^{-1} @ 25°C (Pa.s)	30	34
Shortness Index	2.4	1.8
Tack 50 m/min – 30°C	200	175
Tack 350 m/min – 30°C	630	570
Misting 1.0 cc 50°C	0.40	0.30
Density – 1,5 g/m²	2.05	2.05
Gloss – 1,5 g/m² 60°	23	30
Reactivity @ 120W/cm (m/min)	20	70

Table 5: *comparison of PEA in a cyan pigment dispersion*

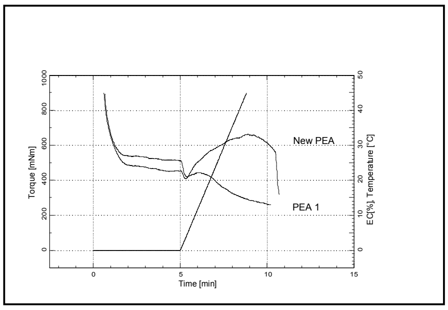


Fig. 7: *lithotronic curve of a cyan pigment dispersion based on PEA 1 and the new PEA respectively*

Besides the improved ink water balance, the new PEA has good pigment wetting properties leading to offset inks with good flow (lower yield value; lower shortness index) and high gloss. Ink tack and misting are lower. Furthermore, the new PEA has a much higher reactivity than existing polyester acrylates, enabling higher printing speeds.

We have seen previously that epoxy acrylates have a negative effect on ink water balance. It is therefore important that the new PEA is able to cope with the impact that the epoxy acrylates have on the emulsion properties of the final ink.
In Fig.8, lithotronic results of cyan inks based on the new PEA, a standard EA and mixtures thereof are shown.
These curves indicate that a fair proportion of epoxy acrylates may be used, without “destroying” the ink water balance completely.

Determination of the final ratio PEA / EA in an ink will be a search for the best compromise between quality and price.

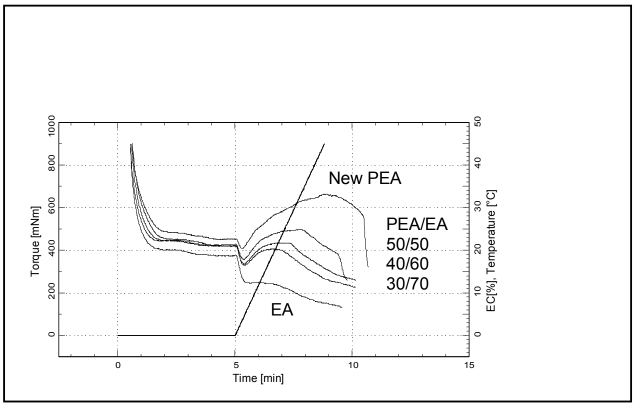


Fig.8: *lithotronic results of cyan inks based on the new PEA, a standard EA and mixtures thereof are shown.*

The new PEA was compared with currently used PEA in a “commercially viable” formulation (see Table 6).

	Ink formulation	
	PEA 1	**New PEA**
PEA	25	25
EA	37	41
GPTA	4	-
Stab 12/1	1	1
Cyan Pigment PB15:3	17	17
Filler	6	6
Photoinitiator blend	10	10
Wax compound	0.5	0.5
	Results	
Visco 2,5 s^{-1}@ 25°C (Pa.s)	72	67
Visco 100 s^{-1} @ 25°C (Pa.s)	30	30
Shortness Index	2.4	2.2
Tack 50 m/min – 30°C	180	150
Tack 350 m/min – 30°C	600	520
Misting 1.0 cc 50°C	0.39	0.34
Density – 1,5 g/m²	1.95	2.10
Gloss – 1,5 g/m² 60°	23	28
Reactivity @ 120W/cm (m/min)	50	90

Table 6: *comparison of results of current PEA 1 with the new PEA in cyan ink formulations.*

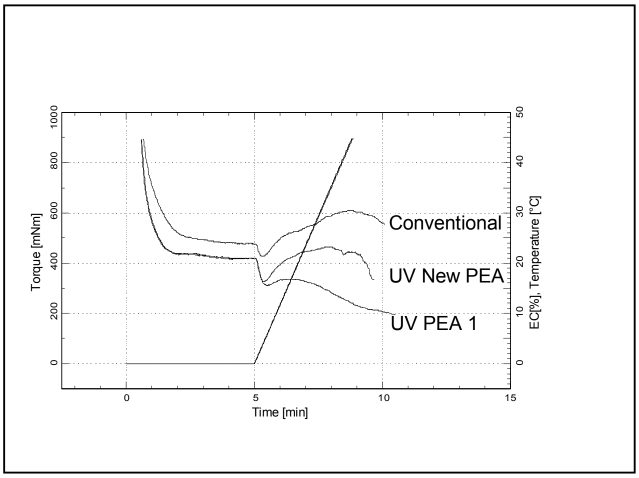


Fig. 9: *lithotronic curve of cyan inks: comparison of UV inks containing PEA 1 and the New PEA (ink formulations Table 6) with commercial conventional sheet-fed ink.*

Results from the cyan inks show that when using the new PEA it is possible to formulate an ink with improved properties such as lower tack and misting, higher cure speed and a more stable ink water emulsion.
These improved ink characteristics are necessary to respond to the ever increasing printing speeds.

Tests in the other colours confirm that the new PEA produce a UV offset ink of a higher quality. Yet, other components also play their role. To optimise ink preformance, choice of pigment and of filler remains important.

Conclusion

UV offset is a well accepted technology in the graphic industry, it leads to improved post press productivity. Press behaviour, however, now needs to be improved.

A new polyester acrylate was developed enabling the production of a UV offset inks with reduced tack, improved misting, higher cure speed and a more stable ink water emulsion. It will permit printing ink manufacturers to produce UV offset inks with improved runnability on press.