A new generation binder for UV offset inks

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Introduction

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

Table 1: Laboratory results for a commercial UV and conventional sheet-fed inks

Property	UV ink	Conventional ink
Viscosity at $0.1s^{-1}$ @ 25°C	500–1000 Pa s	100–700 Pa s
Viscosity at $100s^{-1}$ @ 25°C	35–50 Pa s	30–40 Pa s
Shortness index[1]	15-30	3-15
Tack 50m/min	100–200	100–120
Tack 350m/min	400–700	200–250
Misting 1.0cc 50°C (Optical Density)[2]	0.40–0.60	0.30–0.60
Colour density at $1.5g/m^2$ coverage	1.5(Y)–2.1(B)	1.5(Y)–2.1(B)
Gloss at $1.5g/m^2$ 60°	20–30	20–30
Solvent resistance (acetone double rubs)	>50	1–2

1 Shortness index: ratio of low shear viscosity to high shear viscosity. A shortness index of 1 indicates Newtonian flow behaviour. A higher shortness index implies a more structured and less flowing ink.

2 Misting: ejection of ink particles into the air during ink film splitting between two rollers. It is measured on a Tack-o-scope, set at 50°C with 1g of ink applied. Inks are subjected to a speed of 350m/min for one minute. A white paper is placed under and over the rollers to collect the ejected ink particles. Misting is expressed as the average optical density: the higher the optical density, the more misting.

Measuring the ink-water balance

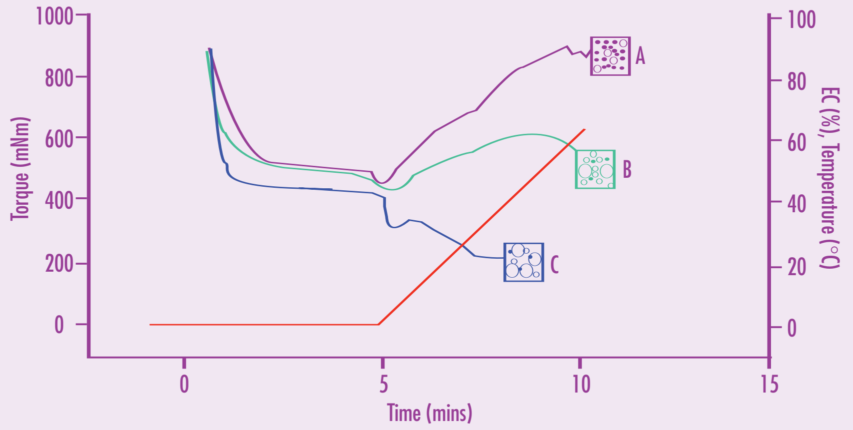
The key property referred to as the 'ink-water balance' was evaluated using a Lithotronic which measures the change in viscosity (in terms of rotational torque) of an ink when water is emulsified into it. The type of ink-water emulsion which is formed has a major impact on the press behaviour and print quality.

Ideally, when water is emulsified into the ink, the viscosity should only undergo a minor increase. This ensures good ink transfer on the press (Type B as shown in Figure 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 in Figure 1). If the emulsion is too coarse (Type C in Figure 1), it can lead to unstable press behaviour, making frequent control of the press necessary.

Type 'C' curves are typical of UV inks, while 'B' curves are typical of conventional inks. It is therefore essential to improve the emulsification behaviour or ink-water balance 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. These parameters, together with pigment wetting, were the subjects of research programmes.

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

Figure 1: Viscosity of different types of ink-water emulsion, measured on a Lithotronic



UV versus conventional lithographic inks

In Table 1, some laboratory test results for commercially available UV and conventional sheet-fed inks are shown. These results were obtained during an evaluation of inks (for use on paper and board as well as for plastics) from five different suppliers.

The most obvious differences are that the UV inks have a higher structure (low-shear viscosity) and higher tack, especially at higher speeds. UV inks form a coarser, less stable emulsion than conventional inks (in line with the remarks concerning Figure 1).

The greater degree of structure can have an adverse impact on ink flow in the ink duct. This structure can be attributed to inferior pigment wetting of the UV binders and the presence of the fillers used to improve misting.

Table 2: General UV offset ink formulation for paper and board (GPTA = propoxylated glycerol triacrylate)

Components	Content	Characteristics
Polyester acrylates	20–30%	Pigment wetting, ink-water balance
Epoxy acrylates	30–50%	Increases reactivity and scratch resistance
High functionality urethane acrylates	0–10%	Increases reactivity and scratch resistance (Black)
Pigment	14–19%	Colour
Fillers	4–8%	Decreases tack and misting
Wax	1%	Increases scratch resistance and slip
Reactive diluent (GPTA)	0–5%	Viscosity adjustment
Photoinitiator blend	8–12%	Initiates cure
Stabilisers, inhibitors	<1%	Improves shelf life

Current UV offset ink formulations

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

The general structures of a range of oligomers are depicted in Figures 2a to 2d.

The general effects which each has on the ink properties may be summarised as follows:

- Polyester acrylate oligomers (see Figure 2a): pigment wetting, ink-water balance in litho inks, adhesion.
- Bisphenol A diglycidyl ether (BADGE)-based epoxy acrylate (see Figure 2b): hard, solvent and water resistant, fast cure, lower cost.
- Fatty acid-modified epoxy acrylate (see Figure 2c): (FA mod EA): Part of the acrylic acid is replaced by a fatty acid (saturated or with C=C bonds). This modification improves pigment wetting and ink water balance, but cure speed is decreased.
- Urethane acrylate (example of a difunctional aromatic UA, see Figure 2d). Physical properties range from soft and plastic to hard and tough. Aromatics are cheaper than aliphatics but more prone to yellowing.

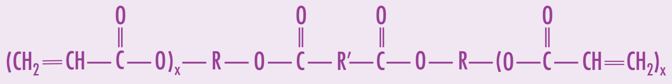
Evaluating oligomers in UV inks

To examine the influence of each component, several oligomers were first evaluated in a cyan pigment dispersion (see Table 3 for formulation). The viscosity was

Table 3: Test formulation for evaluating oligomers

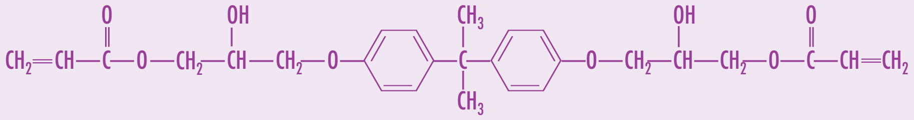
Components	Content (%)
Oligomer	68-x
GPTA	x
Stabilisers, inhibitors	1
Pigment PB15:3	17
Filler	6
Photoinitiator blend	8

Figure 2: Structure of various raw materials used in UV curing inks

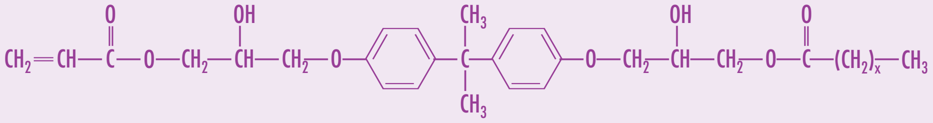


$(CH_2{=}CH-\overset{\overset{O}{\|}}{C}-O)_x-R-O-\overset{\overset{O}{\|}}{C}-R'-\overset{\overset{O}{\|}}{C}-O-R-(O-\overset{\overset{O}{\|}}{C}-CH{=}CH_2)_x$

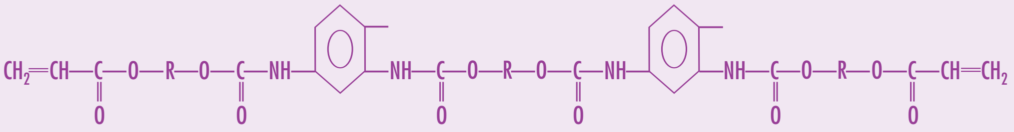
a: Polyester acrylate oligomers (PEA)



b: Bisphenol A diglycidyl ether (BADGE)-based epoxy acrylate (EA)



c: Fatty acid-modified epoxy acrylate (FA mod EA)



d: Urethane acrylate (example of a difunctional aromatic UA)

Table 4: Properties of cyan dispersion based on different oligomers

	PEA 1	PEA2	EA	FA mod EA	UA
Viscosity at 2.5s^{-1} @ 25°C (Pa s)	72	76	67	70	83
Viscosity at 100s^{-1} @ 25°C (Pa s)	30	35	33	31	30
Shortness index	2.4	2.2	2.0	2.2	2.8
Tack 50m/min – 30°C	200	180	200	220	180
Tack 350m/min – 30°C	630	520	650	730	650
Misting (1.0g – 50°C – 350m/min) – OD	0.40	0.44	0.35	0.46	0.37
Optical density at 1.5g/m^2	2.05	2.10	1.90	1.95	1.85
Gloss 60° at 1.5g/m^2	23	24	22	23	19
Reactivity @ 120W/cm (m/min)	20	30	150	80	70

Figure 3: Lithotronic curves of cyan dispersions based on different oligomers

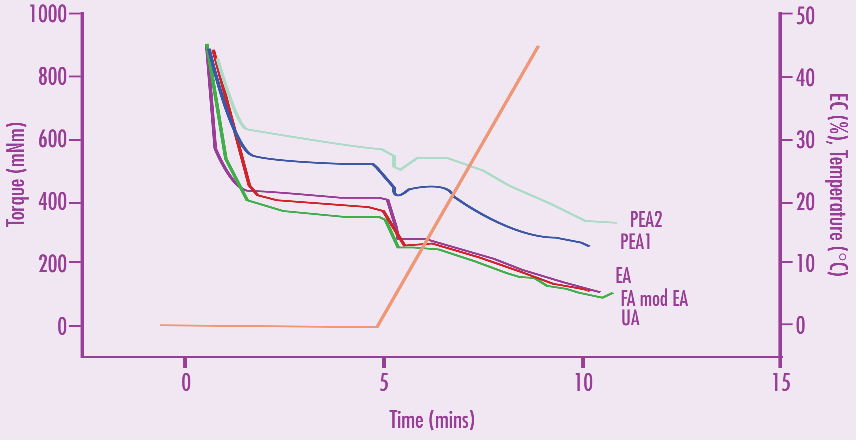
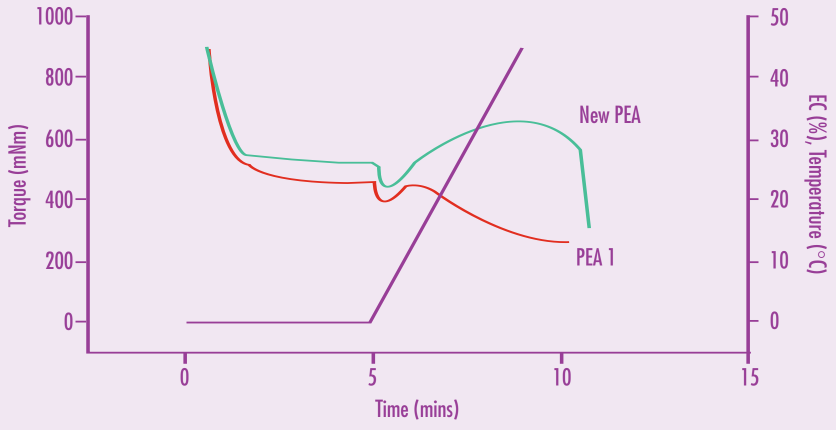


Figure 4: Lithotronic curves of cyan dispersions based on PEA 1 and the new PEA



adjusted to 30 to 40Pa s (25°C) with propoxylated glycerol triacrylate (GPTA).

In Table 4 and Figure 3, the effects of some commercially-available oligomers currently used in the production of UV offset inks are shown. The following oligomers were compared:

- PEA 1: tetrafunctional polyester acrylates (x = 2, see Figure 2a);
- PEA 2: hexafunctional polyester acrylates (x = 3, see Figure 2a);
- EA: Bisphenol A diglycidyl ether (BADGE)-based epoxy acrylate;
- FA mod EA: fatty acid-modified epoxy acrylate;
- UA: hexafunctional aromatic urethane acrylate.

Looking at Figure 3, it is clear that the polyester acrylates have the best emulsification 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 (as shown by the maximum achievable curing speed in Table 4).

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

Different ways to address the above-mentioned points were investigated. Finally, R&D efforts were focused on improving the ink-water emulsification properties of polyester acrylates.

New-generation polyester acrylate

A new polyfunctional polyester acrylate, with a higher molecular weight than existing materials, was developed. A comparison with PEA 1 using the formulation in Table 2 is shown in Table 5 and the emulsification properties are compared in Figure 4.

Table 5: Comparison of PEAs in a cyan pigment dispersion

Property	Cyan ink	
	PEA 1	New PEA
Viscosity at 2.5s^{-1} @ 25°C (Pa s)	72	61
Viscosity at 100s^{-1} @ 25°C (Pa s)	30	34
Shortness index	2.4	1.8
Tack 50m/min – 30°C	200	175
Tack 350m/min – 30°C	630	570
Misting 1.0cc 50°C	0.40	0.30
Density – 1.5g/m2	2.05	2.05
Gloss – 1.5g/m2 60°	23	30
Reactivity @ 120W/cm (m/min)	20	70

Along with the improved ink water balance, the new PEA has good pigment wetting properties, giving offset inks with good flow (lower yield value and lower shortness

Figure 5: Lithotronic results on cyan inks based on the new PEA, a standard EA and mixtures of the two

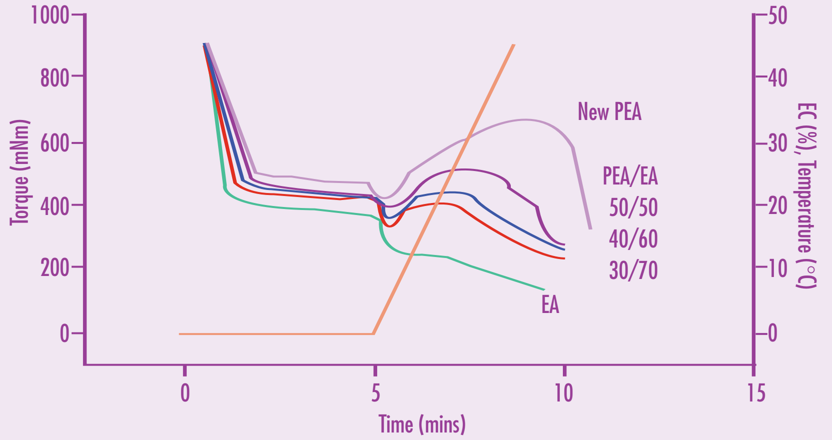


Figure 6: Lithotronic curve of cyan inks: comparison of UV inks containing PEA 1 and the new PEA (ink formulations as in Table 7) with commercial conventional sheet-fed ink

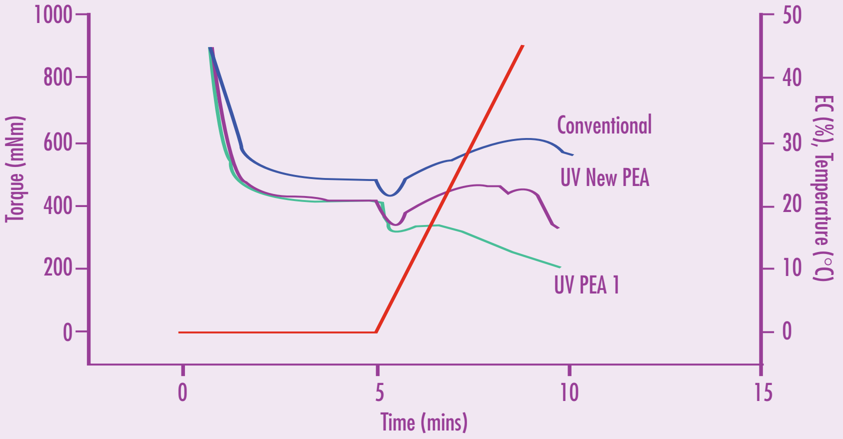


Table 6: Comparison of results of current PEA 1 with the new PEA in cyan ink formulations

Formulation components	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%
Properties		
Viscosity 2.5s^{-1} @ 25°C (Pa s)	72	67
Viscosity 100s^{-1} @ 25°C (Pa s)	30	30
Shortness index	2.4	2.2
Tack 50m/min – 30°C	180	150
Tack 350m/min – 30°C	600	520
Misting 1.0cc 50°C	0.39	0.34
Density – 1.5g/m2	1.95	2.10
Gloss – 1.5g/m2 60°	23	28
Reactivity @ 120W/cm (m/min)	50	90

index) and high gloss. Ink tack and misting are lower. In addition, the new PEA has a much higher reactivity than existing polyester acrylates, permitting higher printing speeds.

It has already been noted that epoxy acrylates have an adverse effect on ink-water balance. It is therefore important that the new PEA should be able to cope with the impact that epoxy acrylates have on the emulsification properties of the final ink.

In Figure 5, lithotronic results are shown on cyan inks based on the new PEA, a standard EA and mixtures of the two. These curves indicate that a fair proportion of epoxy acrylates may be used without completely undermining the ink-water balance.

The determination of the final ratio of PEA to EA in an ink will be a search for the best compromise between quality and price. The new PEA was compared with a currently-used PEA in a 'commercially viable' formulation (see Table 6).

These 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 characteristics are necessary to respond to ever-increasing printing speeds.

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

Conclusion

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

A new polyester acrylate allows the UV offset inks to be produced 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 press runnability.