Magnetic and Thermo-Mechanical Properties of Raw Materials for High Speed Magnetic Ink Character Recognition (MICR) Toners

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Abstract

The standards for MICR printing in the UK, USA, Canada and Australia have been reviewed. Experiments have been carried out on a range of toner formulations to determine their suitability in high speed non impact printer applications to meet the above standards.

The design of popular high speed reader sorters have been examined to determine how the processing of non impact printed cheques affects toner formulation. The mechanism for damage to the non impact printed cheques has been determined by examination of the cheques which have passed through a high speed reader sorter using optical microscopy.

The relationship of the thermo-mechanical properties of the binder polymers to the performance of these toners is considered. This is in terms of reader sorter performance and fuse properties of the toners. Characterisation by rheological measurement, DSC, MFI etc. are described.

Properties of magnetic oxides have been examined in terms of their effect on reader sorter signal levels, toner fixing and MICR document quality.

Toners suitable for a variety of fusing systems are considered i.e. hot roll, flash radiant etc. The results for the toners considered have been evaluated by high reader sorter performance, MICR qualifier signal traces, micrographs of post reader sorter cheques plus a variety of fusing tests.

Introduction

In this paper we will look in particular at MICR toners based on polyester binder resin technology. Polyester resins have benefits in providing useful toner resins for a range of fusing technologies such as radiant, flash and medium high speed hot roll.

MICR cheques have been marketed for a number of years but in some areas such as the UK cheque market acceptance of non impact printing (NIP) of the MICR line has been slow. This has been due to concerns over excessive reject rates and their associated costs. When large numbers of cheques are processed by the main clearing banks, high reject rates can lead to large numbers of cheques requiring manual sorting. This is very expensive. In high volume NIP cheque printing these costs will be passed back to the printer if the fault is due to the print quality of the cheques. Whereas with low volume NIP cheque printing the cheques end up distributed amongst cheques printed by other means and thus problems due to poor toner adhesion or cohesion are less easily attributable to the type of cheque or result in lower reject rates. Thus when high volumes of NIP cheques are printed all aspects of print quality are important especially those affected by toner quality and performance.

In all the cheque areas described below the MICR character font is the E-13B. The E-13B standard sets the specification for the MICR characters. The specification states precise tolerances for height, width plus stroke widths of horizontal and vertical bars. Edge tolerances include irregularity and voids. Voids within the characters and extraneous ink around and within the characters are defined. Character spacing, alignment and skew are also defined within the specification[1]. The 13 within the standard stems from the 0.013inch modular construction used within the character stroke and width. The character set consists of ten numerals and four special symbols.

Table 1. MICR Specification Summary by Country

Country		USA ABA	UK APACS	CAN CPA	AUS APCA
Signal level	High	200%	200%	200%	200%
	Low	80%	50%	80%	50%
Reject Rate		0.2	0.05	0.2	0.25

The signal level 'high' and 'low' refers to the maximum and minimum percentages of the nominal amplitudes of the characters. A reader sorter first magnetises the toner or ink and then the read head detects the flux change due to the leading edge of the character and subsequently each change as further edges are passed through. The flux change is converted to an electronic waveform by the reader sorter. Waveforms[2] for characters 0 and 3 are shown in Figs.1 and 2

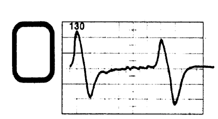

Figure 1 .

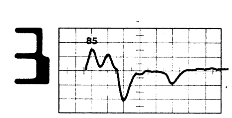

Figure 2.

Two types of high speed reader sorters popular within the banking industry are the Unisys DP1800 series and the IBM 3890. Both machines handle a wide range of documents at very high throughputs. The DP1800 operates at a speed of 300ips (7.61m/sec) and the IBM 3890 330ips (8.37m/sec). In addition to the very high speeds seen by the print it is also subjected to considerably high pressures at the write and in particular the read head. The read head must make good contact with the MICR line even if the cheque has been previously folded and thus maintains a relatively small contact area and consequently exerts a high pressure. These speeds and pressures result in considerable frictional forces being applied to the documents and MICR lines.

Since with NIP cheques the image is slightly raised proud of the paper surface these frictional forces can easily result in damage to the MICR line. This is manifested as toner smearing and in the worst case toner build up on the MICR read head tape. Reject rates then dramatically rise as smears act as extraneous 'ink' and build up can reduce contact between the head and document.

From the following equations it can be used to show that significant transient temperatures can occur during the write/read process. These effects must be considered when selecting materials for MICR toner formulations. Both thermal3 and mechanical properties are therefore important and these effects need to be evaluated.

$$W = uFw \quad (1)$$

$$P = W/t_s \text{ where } t_s = w/v \quad (2)$$

$$q = P/A = (uFw)/(w/v)/A = uFv/A \quad (3)$$

$$\Delta T = \frac{2q}{k}\sqrt{\frac{\alpha ts}{\pi}} \quad (4)$$

(W = frictional Work done on document. u = coefficient of friction. F = Normal force at read head. w = width of read head. P= Heat power developed at read head. t_s = contact time. v = paper speed. A = area of read head. q = heat flux. ΔT = Temperature rise.)

For paper $k = 8.0 \times 10^{-2}$ Wm^{-1} °C^{-1}, $\alpha = 5.91 \times 10^{-8}$ $m^2 s^{-1}$ and u = 0.35. Temperatures of up to 80°C can be reached during the instant spent in the read head nip of a reader sorter

Experimental

Cheque print samples were generated from toners made with three polyester resins suitable for radiant, medium and high speed hot roll fusing. The toners were fused under conditions optimised for each toner type. An oxide 'A' was chosen such that the remanence was sufficient to give toners of sufficient signal level under optimised print conditions of print density, stroke width and background level.

Polyester Resins, Formulations and Toner Preparation

The three polyester resins selected were as described above. These were either used as the sole binder material or combined with a second material (E). This was included both to act as a release aid and more importantly to lower the coefficient of friction of the toner surface. The amount of this second material was chosen to be the maximum to provide the properties described above. Previous work had shown that higher levels provided no further benefits and in fact could be detrimental to the rheological properties of the toners.

Table 2. Polyester Resin Properties

Binder resin	Soft. Point °C	Tg °C	Mw	MFI 125°C 2.16 Kg
Polyester B	80	57	10K	24g/10min
Polyester C	101	63	150K	5g/10min
Polyester D	110	55	250K	15g/10min* 150°C 2.16Kg

Comparison of the rheological properties of the resins are shown below.

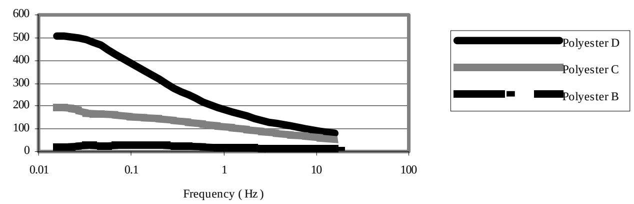

Figure 3. Comparison of the Storage Moduli of the resins

Six toners were prepared by melt blending the oxide with the resins solely or with the additive 'E'. The toners were all milled and classified and post blended to achieve comparable size and physical properties. Toner magnetic saturation (Js) and remanence (Jr) were approximately 43 and 7.5emu/g respectively.

Table 3. Experimental Toner Formulations

Toner	1	2	3	4	5	6
Mag. Oxide	55	55	55	55	55	55
Polyester B	45	40	-	-	-	-
Polyester C	-	-	45	40	-	-
Polyester D	-	-	-	-	45	40
Additive E	-	5	-	5	-	5

Rheology

The viscoelastic properties of the six toners were compared using a TA Instruments CSL500 controlled stress rheometer to evaluate the storage moduli.

Assessment of Print Performance

(a) MICR Signal
Cheque samples were evaluated for average signal strength using a bench top RDM MICR Qualifier.

(b) Fusing
Tests were carried out for the following properties.
i) Tape test
ii) Crease test

(c) Thermal Set-off

An area of MICR line print was placed in a GL heat seal tester and held against some read head tape for 10secs. at 75psi at a range of temperatures.

(d) Reader Sorter Performance

1000 cheques prepared from each of the six toners were run through an IBM3980 high speed sorter to a maximum of 20 passes. Results were assessed for overall percentage failure, read head tape contamination and visual smear.

(e) Microscopy

Micrographs of MICR lines were compared before and after reader sorter tests at x200 using a combination of transmitted and incident illumination with a Nikon optical microscope. Results were recorded by obtaining the images with a Cohu camera and Optimas image analysis software.

Results and Discussions

The thermal set off results in Table 4 indicate as expected that the onset of the lower softening point radiant fusing toner occurs at a relatively low temperature of 80°C. As would be expected the set-off temperature rises significantly for the high m.w. resin based toner. This toner would be less likely to be affected by any thermal effects generated by frictional contact. In all cases but the low m.p. toner the presence of the additive raises the set-off point by approximately 5°C.

Table 4. Thermal Set-Off on Cleaner Head Tape

Toner	1	2	3	4	5	6
70C	No	No	No	No	No	No
75C	No	No	No	No	No	No
80C	Yes	No	No	No	No	No
85C	Yes	Yes	Yes	No	No	No
90C	Yes	Yes	Yes	No	No	No
95C	-	-	-	No	No	No
100C	-	-	-	Yes	No	No
105C	-	-	-	Yes	Yes	No

From Table 5 it can be seen that the fusing properties of all the prints are very similar. The reader sorter results however show a consistent theme. The high speed reader sorter results are all significantly improved when the friction reducing additive is present. This is more pronounced when this material is combined with the higher softening point, higher m.w. binder resins.

Table 5. Toner Fusing and Reader Sorter Results

	Tape %	Crease %	Smear	R/S Fail%	Signal %
Toner 1	99	94	severe	1.52	138
Toner 2	99	97	slight	0.04	120
Toner 3	100	98	severe	0.61	116
Toner 4	98	95	v.slight	0.01	119
Toner 5	100	90	severe	0.41	122
Toner 6	99	93	slight	0.01	124

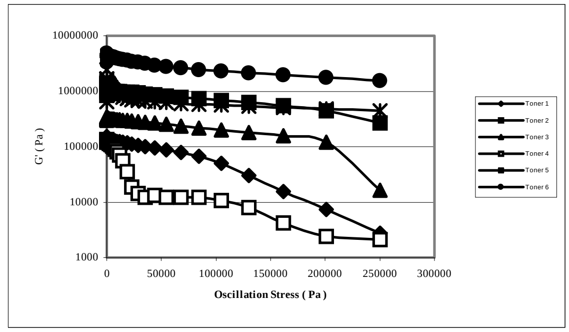

Figure 4. Storage Moduli of Experimental Toners @ 100C

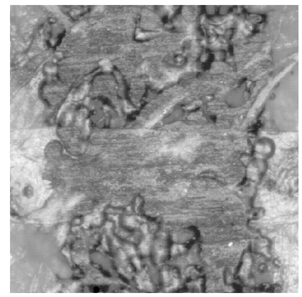

Figure 5. Toner 1

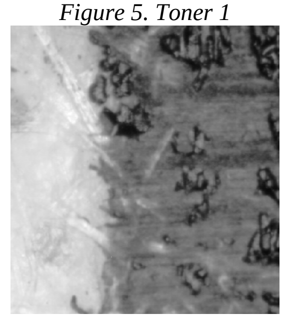

Figure 6. Toner 2

Figure 7. Toner 5

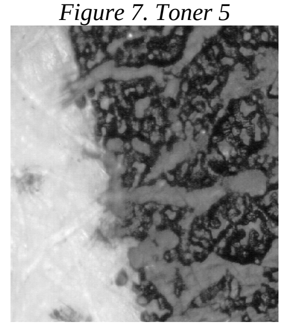

Figure 8. Toner 4

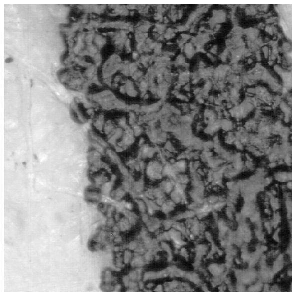

Figure 9. Toner 6

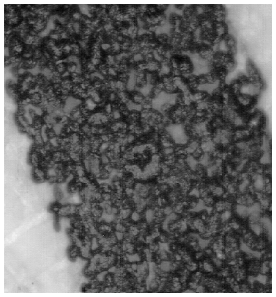

Figure 10. Toner 6 Pre-R/S

Figures 5 - 10 clearly demonstrate the damage inflicted on the toner characters within the MICR line. Toner 1 in fig. 5 is badly smeared and the smearing is certainly mechanical in nature with possibly some thermal element as well. In fig. 6 toner 3 using a higher s.p. polyester also shows heavy smearing which is clearly of a mechanical nature. The effect is similar for toner 5 in fig.7. The binder for all these toners is simply the polyester resin of choice.

Toners 4 and 6 which contains the additive 'E' show little to no damage which is evident when these micrographs are compared to Figure 10. i.e. The micrograph of toner 6 where the cheque has not been subjected to the high speed reader sorter.

Conclusion

MICR toners present some unique constraints when developing a new toner formulation. It is of the utmost importance to include in the binder system an element that can migrate to the surface when the toner is fused . This material's function is to reduce the surface friction of the printed MICR line. Failure to do this will result in mechanical and possibly thermal damage to the printed characters. Care must be taken in the selection of the additive to ensure it does not disrupt the viscous elastic properties of the toners if hot roll fusing is employed. The softening point of the binder system may also be critical and utilising low s.p. materials may also result in damage, high reader sorter reject rates as a consequence.

Acknowledgements

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References

1. Australian Bank's Payment Systems Operations Committee, *Magnetic Ink Character Recognition (MICR),* Publication **No. 3** R2 (1988)
2. Rylla R. Goldberg, *Magnetic Ink Printing & Evaluation Guide,* 1 Seattle .First National Bank, pg no. 23,
3. Holman J.P., *Heat Transfer,* McGraw (1990)

Biography

Ian Neilson obtained a B.Sc. (Hons) Degree in Physics from the University of Exeter in 1973. From 1974 to 1976 he was employed by Gestetner Ltd. as a Research Physicist working on toner development systems. He joined Coates Electrographics in 1976 and a significant portion of his time has been spent in the development of highly successful pressure sensitive radiant and flash fusing magnetic toners for Electron Beam Imaging, in which Coates is a world leader.