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PRINT-THROUGH AS AN INK/PAPER INTERACTION EFFECT IN NEWSPRINT

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Synopsis Functional relationships are derived between print-through (and its components) in newsprint and the fundamental sheet properties of grammage, light scattering coefficient and reflectance factor. The derivation follows the introduction of the concept of pigment penetration depth, together with expressions for the changes in the scattering and absorption coefficients caused by the ink interaction with the fibre network of the paper.

Values calculated using the derived equations are compared with experimental data. The agreement seems acceptable.

List of symbols

R = (luminous) reflectance factor

R_∞ = intrinsic (luminous) reflectance factor of the unprinted sheet with a backing of an opaque pad of unprinted sheets

$R_{\infty\,\text{print}}$ = (luminous) reflectance factor of the reverse side of the printed sheet with a backing of an opaque pad of unprinted sheets

$R_{\infty p}$ = (luminous) reflectance factor of the reverse side of the printed sheet (with the pigment alone) with a backing of an opaque pad of unprinted sheets

$R_{\infty v}$ = intrinsic (luminous) reflectance factor of the pigment-free portion of the model sheet after interaction with vehicle, with a backing of an opaque pad of sheets in the same state

R_o = (luminous) reflectance factor of the unprinted sheet with a black backing, $R = 0$

$R_{o\,\text{print}}$ = (luminous) reflectance factor of the reverse side of the printed sheet with a black backing, $R = 0$

R_{op} = (luminous) reflectance factor of the reverse side of the printed sheet (with the pigment alone) with a black backing, $R = 0$

R_x = (luminous) reflectance factor of the unprinted sheet with a backing of a sheet of the same paper printed with an ink quantity x

k = specific absorption coefficient of the unprinted sheet

Under the chairmanship of Dr J. A. Van den Akker

k_v = specific absorption coefficient of the pigment-free portion of the model sheet after vehicle interaction
s = specific scattering coefficient of the unprinted sheet
s_v = specific scattering coefficient of the pigment-free portion of the model sheet after vehicle interaction.
w = sheet grammage
w_p = pigment penetration depth in the sheet expressed in g/m^2
PT = print-through
PT_{ST} = the show-through component of print-through
PT_{PP} = the pigment penetration component of print-through
PT_{VS} = the vehicle separation component of print-through
PT_p = $PT_{ST}+PT_{PP}$ = the pigment part of print-through

Introduction

PRINT-THROUGH is one of the major ink/paper interaction effects. It refers to the reduction in light reflectance factors on the reverse side of a printed sheet of paper because of the ink applied in a printing process. It is an unwanted effect.

Print-through PT is expressed in accordance with the definition used in practice as—

$$PT = \log \frac{R_\infty}{R_{\infty\ \mathrm{print}}} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where R_∞ = intrinsic reflectance factor* of the unprinted sheet
$R_{\infty\ \mathrm{print}}$ = reflectance factor of the reverse side of the printed sheet

It has been shown earlier[1, 2] that print-through can be considered to be the sum of three different components, each corresponding to a physical phenomenon in the ink/paper system—

$$PT = PT_{ST}+PT_{PP}+PT_{VS} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where PT_{ST} = the show-through component
PT_{PP} = the pigment penetration component
PT_{VS} = the vehicle separation component

The method of breaking up the print-through into components has made it possible to assess quantitatively the magnitude of each of them and to describe qualitatively the situation in the ink/paper system after the ink and paper have interacted with each other. The method has thus contributed to the identification of the physical phenomena giving rise to the resultant situation in the printed sheet.

Subsequent work on the print-through problem has sought to establish a functional relationship between print-through (and its components) and some

* All reflectance factors referred to are luminous reflectance factors, as the measurements have been made with a FMY/C-filter

fundamental paper properties. This paper reports on an attempt in this direction. The approach was based on an idea by Trollsås. After introducing the concept of pigment penetration depth and expressions for the changes in the scattering and absorption coefficients arising from the interaction of the vehicle with the fibre network, the Kubelka-Munk theory of light scattering and absorption in uniform layers was applied to the ink/paper system to derive equations relating print-through and its components to the fundamental sheet properties of grammage, light scattering coefficient and reflectance factor.

Equations relating print-through to fundamental paper properties

Application of the Kubelka-Munk theory

According to the Kubelka-Munk, theory [3, 4] the light reflectance factor R_o of a paper sheet over a black background is—

$$R_o = R_\infty \frac{e^{sw\left(\frac{1}{R_\infty}-R_\infty\right)}-1}{e^{sw\left(\frac{1}{R_\infty}-R_\infty\right)}-R_\infty{}^2} \quad . \quad . \quad . \quad . \quad (3)$$

where R_∞ = intrinsic reflectance factor of the sheet
s = specific scattering coefficient of the sheet
w = sheet grammage

The reflectance factor R_∞ is related to the scattering coefficient s and the absorption coefficient k according to the following expression—

$$R_\infty = 1+\frac{k}{s}-\sqrt{\left(\frac{k}{s}\right)^2+2\frac{k}{s}} \quad . \quad . \quad . \quad . \quad (4)$$

Equations (*3*) and (*4*) apply, according to the premises of the theory, to a homogeneous layer. A sheet of paper can with sufficiently good approximation often be considered as a homogeneous layer in optical evaluations. A printed sheet of paper with ink on it cannot, however, with any reasonable degree of accuracy be treated under the assumption that this approximation should apply.

A model for ink penetration and print-through

The ink transferred to the paper in the printing process penetrates into the paper structure under partial separation of the ink components from each other and influences the scattering and absorption coefficients. The distributions of the ink and its components in the sheet[5] (Fig. 1*a*) are uneven in the Z-direction of the sheet and so consequently is the effect on the scattering and absorption coefficients. Even if it would be basically possible to apply the Kubelka-Munk theory to each infinitesimal sublayer of the sheet and to calculate the integrated effect for the whole sheet, the procedure would be extremely tedious and difficult to survey. A simplifying model was therefore introduced.

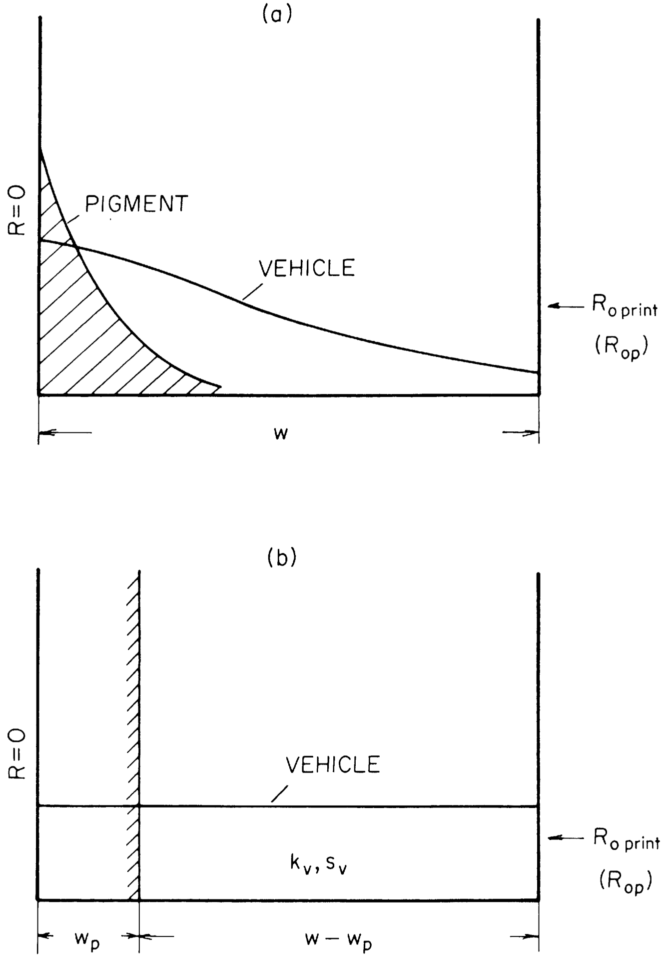

Fig. 1—Pigment and vehicle distributions in (*a*) a printed sheet and (*b*) in the model sheet

In the present approach, the penetration of the pigment and its uneven distribution in the paper depth direction is described by the pigment penetration depth. In this model (Fig. 1*b*), the pigment penetration depth w_p is defined as the depth in a sheet of paper where a plane with the reflectance factor $R = 0$ must be placed to give the same reflectance factor on the reverse side as does the pigment in the printed sheet (pigment alone; the vehicle can be experimentally extracted). The penetration depth is calculated with reference to the grammage of the paper and w_p is therefore expressed in g/m^2.

The model thus comprises a sheet with grammage $w-w_p$ backed with a perfect black surface. The reflectance factor R_{op} for the reverse side of this substituted model sheet is obtained by application of equation (*3*), giving—

$$R_{op} = R_\infty \frac{e^{s(w-w_p)\left(\frac{1}{R_\infty}-R_\infty\right)}-1}{e^{s(w-w_p)\left(\frac{1}{R_\infty}-R_\infty\right)}-R_\infty^{\,2}} \quad . \quad . \quad . \quad (5)$$

So long as the effect of the pigment alone and not that of the vehicle is considered, R_∞ is still given by equation (*4*).

An additional effect stems from the presence of the ink vehicle in the substituted sheet, giving this system a scattering coefficient s_v. The difference $s-s_v$ denotes the reduction in the scattering coefficient of the paper through the vehicle interaction.

In the same manner, the vehicle effect on the absorption coefficient can be described: k_v is substituted for k and k_v-k denotes the increase in absorption coefficient of the paper through the vehicle interaction. This change is usually due to the presence of pitch and dyes in the mineral oil.

The reflectance factor $R_{o\,\mathrm{print}}$ for the reverse side of the model sheet is then—

$$R_{o\ \mathrm{print}} = R_{\infty v} \frac{e^{s_v(w-w_p)\left(\frac{1}{R_{\infty v}}-R_{\infty v}\right)}-1}{e^{s_v(w-w_v)\left(\frac{1}{R_{\infty v}}-R_{\infty v}\right)}-R_{\infty v}^{\,2}} \quad . \quad . \quad . \quad (6)$$

The term $R_{\infty v}$ denotes the intrinsic reflectance factor of the model sheet resulting from the vehicle interaction and may be expressed, equation (*4*), as—

$$R_{\infty v} = 1+\frac{k_v}{s_v}-\sqrt{\left(\frac{k_v}{s_v}\right)^2+2\frac{k_v}{s_v}} \quad . \quad . \quad . \quad . \quad (7)$$

Unlike the other reflectance factors employed here, $R_{\infty v}$ cannot be measured directly on the printed sheet.

Equations for print-through and its components based on the model

Since $R_{o\,\mathrm{print}} \approx R_{\infty\,\mathrm{print}}$ for sufficiently large ink quantities (for the standard news ink on newsprint above, about 2 g/m^2), the expression for the reflectance factor as given by equation (*6*) can be substituted for $R_{\infty\,\mathrm{print}}$ in the definition equation (*1*) to give the print-through of the printed sheet as derived by means of the model here introduced—

$$PT = \log\left[\frac{R_\infty}{R_{\infty v}}\cdot\frac{e^{s_v(w-w_p)\left(\frac{1}{R_{\infty v}}-R_{\infty v}\right)}-R_{\infty v}{}^2}{e^{s_v(w-w_p)\left(\frac{1}{R_{\infty v}}-R_{\infty v}\right)}-1}\right] \quad . \quad . \quad (8)$$

The show-through component PT_{ST} of the print-through is defined as—

$$PT_{ST} = \log\frac{R_\infty}{R_x} \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

where R_x = reflectance factor for a sheet of paper placed above a sheet of the same paper printed with an ink quantity x.

For sufficiently large ink quantities, the approximation $R_x \approx R_o$ holds within the limits of experimental accuracy. For newsprint and the standard news ink used, the limiting ink quantity is approximately 2 g/m². Equation (*9*) can in such cases with good approximation be written—

$$PT_{ST} \approx \log\frac{R_\infty}{R_o} \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

The introduction of the expression for R_o according to equation (*3*) into equation (*10*) gives the show-through components—

$$PT_{ST} \approx \log\frac{e^{sw\left(\frac{1}{R_\infty}-R_\infty\right)}-R_\infty{}^2}{e^{sw\left(\frac{1}{R_\infty}-R_\infty\right)}-1} \quad . \quad . \quad . \quad . \quad . \quad (11)$$

To find the other two print-through components, the sum $PT_p = PT_{ST} + PT_{PP}$ is first calculated. This sum denotes the total part of the print-through caused by the ink pigment. This part is defined as—

$$PT_p = PT_{ST}+PT_{PP} = \log\frac{R_\infty}{R_{\infty p}} \quad . \quad . \quad . \quad . \quad (12)$$

As before, $R_{\infty p} - R_{op} \leqslant 0$, so that equations (*5*) and (*12*) give—

$$PT_p \approx \log\frac{e^{s(w-w_p)\left(\frac{1}{R_\infty}-R_\infty\right)}R_\infty{}^2}{e^{s(w-w_p)\left(\frac{1}{R_\infty}-R_\infty\right)}-1} \quad . \quad . \quad . \quad . \quad (13)$$

The calculation of the two remainig print-through components then follows from equations (*2*), (*8*) and (*13*).

Notes on the model

The model sheet is one-dimensional and, when substituted for the actual printed sheet as a basis for the derivation of the print-through equations, it takes into consideration only variations in the *Z*-direction of the actual sheet. The choice of such a model is made on the merits of simplicity, neglecting the fact that the material and property distributions along various perpendiculars through the sheet in the *Z*-direction differ from each other. Microdensitometer measurements by Nordman & Makkonen[6] show, for example, that the reflectance factor varies over the reverse side surface of the printed sheet, which indicates a variation in the ink (ink components) penetration into the sheet and/or a variation in the paper properties in the XY plane of the sheet. The model therefore applies strictly only to average distributions over areas great enough to have mean conditions insensitive to the area size. In all the cases studied, the application of the derived formulae suggests that the model works satisfactorily at least for areas 30 mm in diameter (usual measuring area for the Elrepho reflectometer). When the area approaches the size of flocs, special precautions have to be observed. It seems reasonable, although it has not yet been studied, to assume that the model serves well only for comparing different papers with approximately the same kind of ink pigment distribution.

The ink vehicle distribution in the Z-direction varies with time and tends to a fairly even equilibrium distribution through the sheet. After time intervals that are of practical interest, the distribution is rather flat.[5] Furthermore, experiments have indicated that the average scattering coefficient for the sheet tends to become practically constant even before the final equilibrium vehicle distribution is reached. It appears reasonable therefore to assume an even vehicle distribution in the model.

The model does not in its present form explicitly account for the quantity of ink applied to the printed paper. Comparison of different papers presupposes that they are printed with the same quantity of ink.

Influence of paper properties on print-through

THE print-through equations express the print-through dependence upon—

1. The fundamental paper properties of grammage, reflectance factor, scattering coefficient and absorption coefficient.
2. The end use parameters of pigment penetration depth and the changes in scattering and absorption coefficients of the paper caused by the ink.

These equations make it possible to calculate the print-through and the effects upon print-through when the properties of a given paper are altered within a limited range. Possible interaction effects between the altered variables are neglected.

The fundamental paper properties are determined by ordinary standard methods. The end use parameters are determined as follows.

Pigment penetration depth is calculated by means of equation (*5*) with values of R_∞, w and s determined on the original paper. Value $R_{op} \approx R_{\infty p}$ (for ink quantities equal to or greater than 2 g/m²) is determined on a test-printed sheet from which the ink vehicle has been extracted.

It can here be mentioned that the pigment penetration depth has been experimentally determined for a series of more than 40 commercial newsprints test-printed according to SCAN P 35:72. An ink quantity of 2 g/m² was applied to the paper, giving a print density of approximately 0·85. The pigment penetration depths were found to range 5–9 g/m².

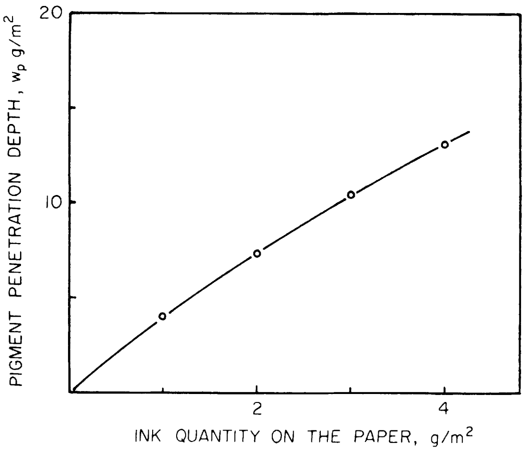

Fig. 2—Pigment penetration depth as a function of ink quantity on the paper

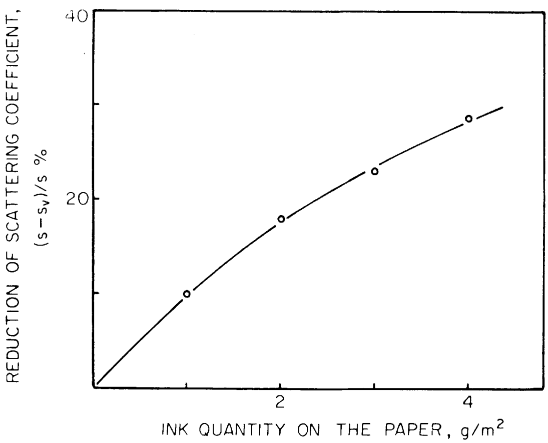

Fig. 3—Reduction of the scattering coefficient as a function of ink quantity on the paper

The value of the pigment penetration depth is slightly influenced by the residual ink pitch in the printed sheet after the extraction of the ink vehicle.

The residual pitch of the ink vehicle has been found to decrease the value of R_{op} by up to 0·4 units, which corresponds to an increase of 0·4 g/m² in pigment penetration depth.

The pigment penetration depth in a given paper depends upon the quantity of ink applied. This is illustrated for a typical newsprint in Fig. 2.

Changes in scattering and absorption coefficients may be calculated by means of equations (*6*) and (*7*) from adequate experimental data, but considerable experimental work is required to obtain the necessary data in each case. A way of avoiding this inconvenience has been sought. It was found in special experimental series that the change in scattering coefficient dominates over the change in absorption coefficient. For a number of newsprints printed with 2 g/m² of the standard newsink, the change in scattering coefficient has been found to range 13–17 per cent, whereas the absorption coefficient ranged 2–3 per cent. The approximation was therefore introduced that the changes in scattering coefficient and absorption coefficient together could be represented by a calculated change in scattering coefficient. This approximation means that the absorption coefficient for the paper alone (without ink vehicle) k can be substituted for k_v in equation (*7*).

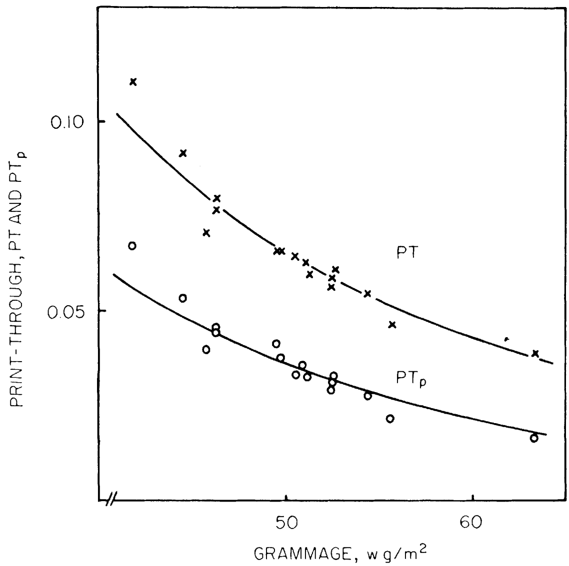

Fig. 4—Print-through and pigment part of print-through for a given ink quantity as functions of grammage of the sheet: the curves are calculated, but the points represent experimental data

The change in scattering coefficient is calculated from the relevant experimental data by means of equations (*6*) and (*7*) in a manner analogous to the calculation of penetration depth.

The change in scattering coefficient depends upon the quantity of vehicle released from the ink into the paper. This quantity varies with the quantity of ink applied. Fig. 3 shows the reduction in scattering coefficient as a function of applied quantity of ink. When studying the effects of changes in grammage, the fact that the vehicle concentration in the model sheet is changed in spite of a constant ink quantity (that is, constant vehicle quantity) has to be taken into account. It has here been assumed that the change in scattering coefficient due to this effect is proportional to the vehicle concentration in the model sheet. This is the same as to say that the change is inversely proportional to the grammage. This appears to be a reasonable assumption when small variations within a limited range on each side of a given grammage value are being considered.

Verification of the print-through equations

IN ORDER to test the validity of the derived print-through equations, a number of commercial newsprints were printed and the print-through and the pigment part of print-through were calculated. These newsprints were selected from a large paper population to form three separate series— one series of papers with mainly the grammage varying, one with mainly the reflectance factor varying and one with mainly the scattering coefficient varying. In each series, the properties other than that deliberately varied were almost constant (the variation was in general less than 4 per cent).

The dependence of print-through on fundamental paper properties has been calculated, taking the variables in these three series of newsprints in turn, by applying equations (*8*) and (*13*) and the approximate relationship—

$$\left[\frac{s-s_v}{s}\right]_w = \frac{52}{w}\cdot\left[\frac{s-s_v}{s}\right]_{52} \quad . \quad . \quad . \quad . \quad (14)$$

where the suffixes w and 52 denote, respectively, the sheet of grammage w g/m^2 and the reference sheet of grammage 52 g/m^2.

The experimentally found values of print-through and of the pigment part of the print-through are plotted against the varied fundamental paper property in Fig. 4–6, together with the calculated curves. The average value of each property for the papers studied was used as the initial value for the calculations.

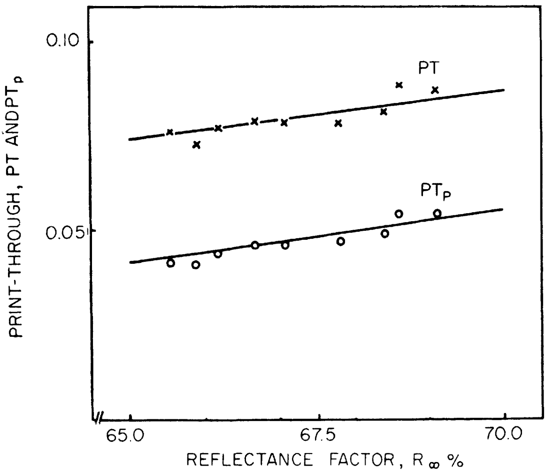

Fig. 5—Print-through and pigment part of print-through for a given ink quantity as functions of the reflectance factor of the sheet: the curves are calculated, but the points represent experimental data

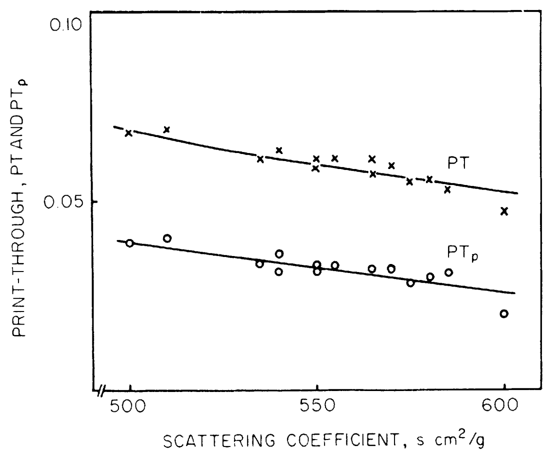

Fig. 6—Print-through and pigment part of print-through for a given ink quantity as functions of the scattering coefficient of the sheet: the curves are calculated, but the points represent experimental data

The agreement between experimental values and values predicted by the derived print-through equations seems to be good enough to justify the conclusion that the simplifying assumptions made in the derivation of the equation are justified and that the relationships expressed by the equations are accurate enough to permit predictions from data obtained by standardised test printing.

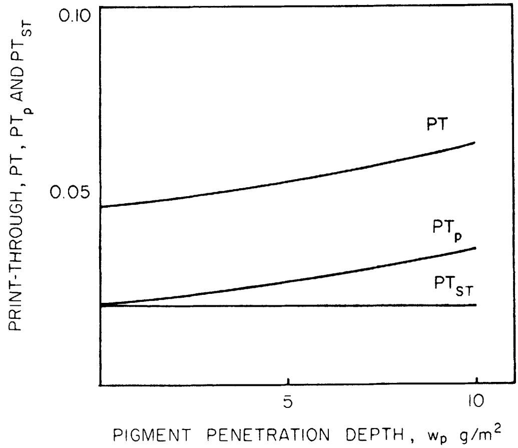

Fig. 7—Print-through, pigment part of a print-through and show-through for a given ink quantity as functions of pigment penetration depth: the curves are calculated with the initial values given in Table 1

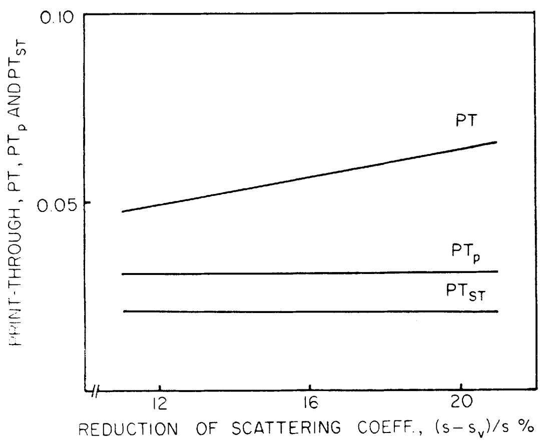

Fig. 8—Print-through, pigment part of print-through and show-through for a given ink quantity as functions of the reduction of the scattering coefficient due to the vehicle interaction: the curves are calculated with the initial values given in Table 1

The dependence of print-through on the end use parameters was calculated in a similar manner. The results for a typical newsprint are shown in Fig.7 and 8.

Changes in the various variables that produce a change in print-through of $0{\cdot}5 \times 10^{-2}$ at constant ink quantity have also been calculated for a typical newsprint with the values $w = 52$ g/m², $R_\infty = 65$ per cent, $s = 550$ cm²/g, $w_p = 7{\cdot}5$ g/m² and $(s-s_v)/s = 0{\cdot}17$ (Table 1).

TABLE 1—CHANGES IN DIFFERENT VARIABLES THAT PRODUCE A REDUCTION IN PRINT-THROUGH OF $0{\cdot}5 \times 10^{-2}$ IN A STANDARD SHEET WITH A GIVEN INK QUANTITY

Fundamental paper property and end use parameter	*Value of the reference sheet*	*Change*
Grammage	52 g/m²	+2·0 g/m²
Reflectance factor	65 per cent	−2·8 per cent
Scattering coefficient	550 cm²/g	+35 cm²/g
Pigment penetration depth	7·5 g/m²	—2·5 per cent
Relative change in scattering coefficient	17 per cent	−2·6 per cent

References

1. Larsson, L. O., 'Physical background of some terms used to describe print quality', *Advances in Printing Science and Technology*, Ed. W. H. Banks (Pergamon Press, London, 1969), Vol. 5, 115–119
2. Larsson, L. O. and Trollsås, P. O., *Svensk Papperstidn.*, 1972, **75** (8), 317–321
3. Kubelka, P. and Munk, F., *Z. Techn. Physik*, 1931, **12**, 593
4. Kubelka, P., *J. Opt. Soc. Amer.*, 1948, **38**, 448
5. Larsson, L. O. and Trollsås, P. O., 'Studies of ink interaction with paper by means of radioactive tracers', *Advances in Printing Science and Technology*, Ed. W. H. Banks (Pergamon Press, London, 1969), Vol. 5, 121–131
6. Nordman, L. and Makkonen, T., 'Studies of print-through by means of unevenness measurements', *Advances in Printing Science and Technology*, Ed. W. H. Banks (Pergamon Press, London, 1971), Vol. 6, 271–281

Transcription of Discussion

Discussion

Mr G. F. Underhay I believe that, in our printability discussions, we have rather forgotten some of the good work that was done 10 or more years ago. I would like to refer especially to a paper by G. L. Larocque (*Pulp & Paper Mag. Can.*, 1967, **68** (1), T16) of the *New York Daily News* and formerly of PPRIC. Gerry was very down to earth and, as I remember his conclusions, he hardly mentioned things like tear, tensile and burst. Instead, based on 20 years of detailed records, he showed that satisfactory runnability was linked with good stretch characteristics, better winding, higher moisture content, minimum roll damage and low shive content (consequent upon improved shive removed facilities in the papermills). Thus, he moved substantially away from tests on ridiculously small bits of paper, which may well be completely unrepresentative; he studied whole rolls rather than square centimetres. How otherwise can you spot a single shive or other potential fracture points as being likely to cause a break in several miles of paper? (For further comments and references, particularly to George Sears, see my paper 'Mechanical Pulp —the Neglected Gold Mine', *Tappi*, 1968, **51** (9), 39A.)

Dr L. S. Nordman Prof. Renata Marton did not mention the time lag between printing and splitting of the sheet of paper. It must have a profound influence on the appearance and situation of the maximum value, because we have found that there is a marked redistribution of the vehicle in the sheet when the time after printing increases.

Prof. Renata Marton We did not split right away after printing, because it is impossible to split 14 or 15 layers very fast, though we consider the time to be very important. We have not yet determined how long the vehicle continues to migrate, but we intend to do so. The time between printing and testing was about 15 min.

Dr J. Marton As Mr Underhay has already mentioned, the runnability of newsprint is more affected by mechanical condition of the roll and by the

Under the chairmanship of Dr J. A. Van den Akker moisture content than by some other fundamental paper properties like tear or smoothness. Nonetheless, printability problems are quite important for other categories of paper like fine papers coated or uncoated used for more quality printing. We should not therefore consider everything from the point of view of newsprint.

Dr J. Grant I am not quite clear how Prof. Marton's method, which intrigues me very much, differentiates between the progress of the pigment and the progress of the ink vehicle through the thickness of the paper. One illustration showed both as separate curves; but, if she activates the ink as a whole, how is one distinguished from the other?

I would like to add a few remarks of a general nature, which suggest themselves to me as a result of listening to the papers this week.

I am all with George Underhay in that we should try to keep our feet on the ground in the practical applications of the knowledge that we are hearing about, although this symposium is of course concerned with the fundamental properties of paper as distinct from their immediate practical use.

I have always regarded paper as having properties in equilibrium. Thus, when you attempt to improve one property, you invariably lose on another. The simplest example I suppose is the one I mentioned the other day—when one beats pulp to improve strength, one loses opacity, dimensional stability and one can give many other examples. So the problem really arises how can we take this welter of complicated factors that go to make up good printability or runnability and find optimum compromise among them all to give the best results on the papermachine.

My suggestion is of course not original—I know that it has been applied, especially in North America. I refer to furnish optimisation, which I believe is the real answer to the practical application of these recondite properties. I have carried out large-scale experiments on this and was very impressed by the results obtained by feeding into a computer the desirable characteristics from a number of different pulps—hardwood pulps, long-fibred pulps and others—and programming the computer to give the proportions that we should use and how we should treat the pulps in order to obtain the best combination of printing characteristics. I believe that this is really going to be the best way of achieving something practical out of the theory that we have heard during the course of this meeting.

Prof. Renata Marton I was rather expecting this question. We were unable to provide specific information about the distribution of the radioactive tracer between the carbon black and the ink. We are working on this now, but we assumed equal specific activities of the carbon black and the ink vehicle. We know, however, that errors are introduced by this assumption, but they should not affect the qualitative conclusion I have presented.

Dr J. Grant The difficulty is that the vehicle and the carbon black travel through the paper at different rates and to different extents. Unless you separate their effects, the results are really meaningless.

Prof. Renata Marton Observation under the microscope of each layer helped to establish where the carbon stopped and how the vehicle continued to migrate. I presented a few examples of what we are doing, but the work is not finished and we hope greatly to improve on this promising method.

Mr R. Rahkonen I would like to add one point that might be of interest. I think it might be possible separately to label the pigment and rhe vehicle with two labelling substances having different spectra of radioactive radiation. Then it should be possible using Prof. Marton's technique to measure separately the amounts of pigment and vehicle in the different layers of the paper simply by measuring the intensity of radiation at two different wavelengths. At Rauma, we have used the same technique to measure separately the flow of wood chips and of coating liquor in a continuous digestion system.

Mr J. R. Parker May I ask Prof. Marton how her work compares with that by Larsson, who has used similar techniques?

Prof. Renata Marton Yes, we know of Dr Larsson's work very well and we co-operate closely. He uses a Geiger-Müller counter, which is much less sensitive than a liquid scintillator counter, for this counts a hundred times less radioactivity than a Geiger-Müller counter. Our curves are similar to some extent, therefore, but we regard the scintillation method to permit much greater precision, since we can detect parts of milligrams of ink in each layer.

Dr A. B. Truman It is intriguing to think that one might be able to feed into a computer the basic physical data on paper properties to obtain from it the desirable printing characteristics of the sheet (which I would suspect are very difficult to define).

In my opinion, the problem is more educational than technological. The papermakers must be educated to make a consistent product with controlled properties and the printer must learn to use the paper in an intelligent way. I can cite an example of a troubleshooting job that I went on recently; a printer of newsprint had had considerable web breaks on his machine. On questioning him closely, I discovered that the firm had recently installed air conditioning equipment that considerably reduced the ambient moisture content. I explained to him the relationship between that and paper properties, the tensile strength and stretch—and really that in itself was the solution to the problem.

However erudite our study of the factors contributing to good printability and runnability, the effort will be to no avail if we do not communicate effectively with the papermaker and the printer.