Rheological Characterization of Printing Inks: Correlations Between Laboratory Measurements and Press Performance

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Rheology, Rheometer, Viscoelasticity, Viscosity, Tack

Abstract

The main purpose of rheological measurements applied to printing inks is the prediction of their press perfomance. During the last two decades, inkmakers and printers have found the characterization of the viscoelasticity of printing inks increasingly useful in addition to the more straight forward flow properties. As a consequence, new quality criteria are being elaborated on the basis of this more thorough approach. However, difficulties of interpretation remain, including a certain lack of correlations between laboratory and press performance. Moreover, standardization of the test procedures is still needed. The aim of this communication is to give, on the one hand, a review of the existing techniques related to the different rheological measurements on printing inks, namely viscosity data over a wide range of shear rates, dynamic aspects, viscoelastic properties, characterization and control of offset ink emulsions and tack. On the other hand, the scientific relevance and the practical implications of the laboratory results will be discussed. Examples stemming from the study of tack of offset inks are presented.

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Introduction

Rheological properties of inks have been the subject of many studies for several decades. The scope of such tests has always been the prediction of the performance of an ink in the printing process.

The aim of this work is not to give another demonstration of the obvious relevance of the study of these properties, but rather to clarify some specific points concerning the use of rheometry in the prediction of the behavior of an ink in the printing situation. Two major difficulties arise when one considers this investigation: (i) printing inks are concentrated suspensions of pigments in a polymer solution, i.e. complex liquids, which implies that most theoretical considerations related to model fluids do not apply to them; (ii) there is still a lack of fundamental understanding of the detailed nature of the physical processes, e.g. when an ink splits at the exit of a printing nip.

The latter problem has been tackled by Pangalos and Dealy [1985], who consider that there are two approaches to the question of rating inks on the basis of laboratory measurements. One approach is to make a hypothesis on which properties are important and make an accurate measurement of these properties. Essential and desirable data should be shear viscosity (η), flow curves ($\eta=f(\dot{\gamma})$), thixotropy and viscosity/temperature relationships, dynamic viscosity (η'), storage and loss moduli (G' and G''), relaxation time and extensional viscosity (η_E).

The second approach is to use a test procedure that simulates, to some extent, the printing process. In this case, the test gives an empirical index of ink quality, rather than a well-defined physical characterization. Tack measurements or emulsification tests are typical examples of such tests and are very commonly used by inkmakers and printers.

These two approaches are illustrated and discussed in the present work.

I. Practical ranges of variables which affect rheological properties and corresponding measurement tehniques

The complex nature of the rheological properties of inks requires the specification of several parameters, such as shear rates, oscillation frequency, in the viscoelastic experiments, temperature and "shear history".

I.1. Shear rates, shear-thinning behavior

It is commonly assumed that the behavior of inks on press is controlled by shear rates, of the order of 10^6 s^{-1} in the printing nip [Oittinen, 1976]. In fact, during printing, inks undergo a great variety of shear rates. Since these fluids are generally non-newtonian and exhibit a certain degree of elasticity, it is necessary to make measurements with a wide range of shear rates. Attempt should be made to simulate the process conditions by making the measurements at deformation rates as close as possible to those encountered in practice.

Table 1 shows the approximate magnitude of the shear rates and the corresponding situations typically encountered in the printing industry [from Barnes, 1989]. The shear rate domain of interest for printing inks is quite wide, since it covers in principle 12 orders of magnitude, from 10^{-6} to 10^6 s^{-1}. In practice, it is more frequent to study the ink properties over a narrower range, namely 10^{-3} -10^{-2} s^{-1} and 10^5-$10^6 s^{-1}$.

General description of the situation	Typical range of shear rates (s^{-1})	Situation in printing
Sedimentation of fine powders in a suspending liquid	$10^{-6} - 10^{-4}$	Pigments in the ink vehicle at rest, e.g. during storage
Leveling due to surface tension	$10^{-2} - 10^{-1}$	Ink or varnish film just after the transfer onto the substrate
Draining under gravity	10^{-1} - 10^{1}	Ink setting on paper
Pumping	10^{0} - 10^{3}	Ink feeding
High speed coating	10^{5} -10^{6}	Ink tranfer, printing nip

Table 1 : Typical shear rates encountered in printing [from Barnes, 1989]

Many studies have tried to give accurate estimates of the maximum shear rates in a printing nip [Mewis and Dobbels, 1981; Zang *et al.*, 1991; Mac Phee, 1997]. This problem is complex, due to the fact that the nip is generally constituted of two rotating rollers with different mechanical (elastic) properties. Consequently, the evaluation of the ink film thickness is not easy, especially in dynamic conditions. It is generally assumed that this thickness is much smaller than 10 μm. According to Mac Phee [1997], a 1.75 μm-thick film is needed in the nip in the case of

coated paper (versus 2.20 μm for uncoated paper, e.g. newsprint) to tranfer the typical 1 μm thickness onto the substrate.

Figure 1 gives a synthetic view of the shear rates in printing process and the suitability of the corresponding rheometers. None of these apparatuses can cover the entire shear rate range, but different types of rheometers may be complementary.

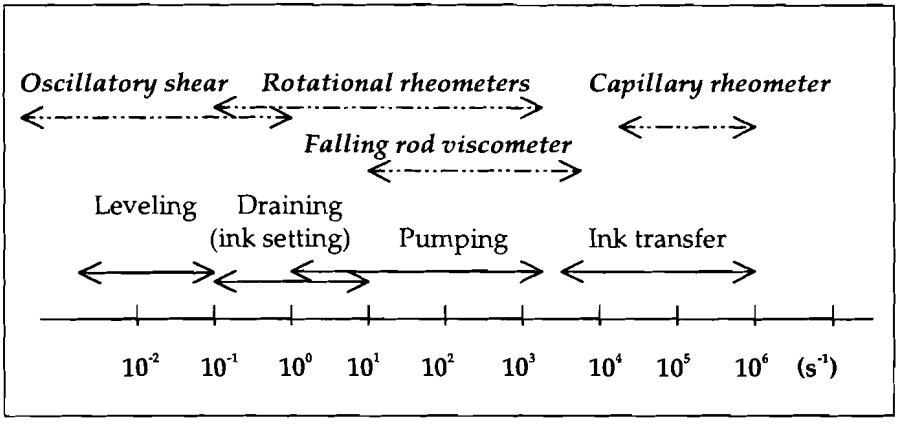

Figure 1 : Shear rates in printing processes
and correspondingly suitable rheometers

Estimations of viscosity values have been usually performed on rudimentary viscometers, like the falling-rod viscometer for offset inks, and the cup viscometers for flexo inks. These instrumentss are easy to use and inexpensive, but their temperature is not well controlled, and the fluid is not subject to a uniform shearing time. Nevertheless, Pangalos and Dealy [1985] found that the falling rod viscometer gave reasonably precise values of the steady shear equilibrium viscosity of inks at high shear stresses. However, these viscometers are unsuitable to quantify the non-newtonian properties of the inks. More recently, Chou [1992] performed experiments on a axial controlled-rate rheometer (a reverse of the falling rod viscometer), up to 10^4 s^{-1}, and obtained the viscosity-profile curves of inks, using the Cross equation.

Shear-thinning behavior is a common feature of printing inks and has been extensively studied in the literature. Several mathematical models (σ versus $\dot{\gamma}$, or η versus $\dot{\gamma}$) have been used to describe this feature. The

interested readers will find more details in the relevant references [e.g. Barnes et al., 1989].

Rotational rheometers (Couette flow) have been extensively used to analyse the rhelogical behavior of inks at low-to-medium shear rates [Chou, 1991; Chou, 1992;]. Cone-plate configurations are generally suitable for a large variety of printing inks, provided the appropriate geometries are selected. Under a critical shear rate, this mode has the advantage to give a constant shear rate, whatever the distance from the axis of rotation. Moreover, the temperature on these rheometers is well-monitored, which allows the analysis of temperature dependence of ink flow, and the extent of thixotropy to be established.

However, the conditions of these experiments are limited in shear rates. Typically, the shear rates examined are 10^{-3} to 10^{2}-10^{3} s^{-1}. Above these values, flow instabilities may appear, and lead to the interruption of the measurement. Due to these limiting conditions, the maximum shear rate value may be only 10^{1} s^{-1} for certain offset inks, and 10^{3} s^{-1} for flexo inks.

The analysis of the ink properties at shear rates above 10^{4} s^{-1}, which reflect the most critical situation on a press, remains much more difficult. This type of study requires a capillary rheometer (Poiseuille flow), which calls upon even more experimental caution than rotational rheometers, and this explains why they are seldom used for printing inks. Nevertheless, this technique is particularly helpful for the formulators of coating colors. [Wilson and Greenblatt, 1995]. One can expect a development of these measurements in the context of printing inks.

I.2. Characteristic times, influence of the viscoelastic properties of the ink

It is generally accepted that an ink will behave more like an elastic material, when subjected to strains that occur during times shorter than its relaxation time. This situation applies to film splitting, as pointed out by Zang et al. [1991] and many other authors previously [Oittinen, 1976; Mewis and Dobbels,1981; Lyne, 1989]. Specifically, their measurements indicated that the time required to split the ink film thicknesses normally found on press are well under 10^{-3} s, at typical press speeds. In other studies [Oittinen et al., 1992; Amari and Wanatabe, 1983], the relaxation times for typical news inks were found to range from 0.02 to 0.4 ms at shear rates of the order of 10^{3} s^{-1}. Inkmakers appreciate the characterization of the viscoelasticity of printing inks as a useful addition to the more conventional flow analysis. An extensive effort has been

made to use these techniques. New quality criteria are being elaborated on the basis of this more thorough approach, but the difficulty is precisely to choose the adequate criteria. Classically, the variations of the elastic modulus (G') and the dynamic viscosity (η') vs. frequency are considered. The loss tangent is also a useful indication of the extent of the elastic vs. viscous character of the ink. The range of frequencies examined must correspond to the practical situation, which is in fact difficult to asess. Earlier studies [Lewis and Spaull, 1975] had already considered a wide range of frequencies (3 to 8.5 10^4 Hz), which is pertinent, according to the dwell time of the ink in the printing nip. Another attempt to examine the high frequency region (10^4 to 10^6 Hz) was made in our laboratory [Blayo et al. 1996, 1997].

The evolution of these features as a function of temperature is also of prime importance, particularly in the waterless process [Durand and Wasilewski, 1996; Lanet et al., 1997].

The oscillatory measurements also offer the advantage of analyzing liquids which display slip at the wall of the measurement vessel, or sample fracture in steady-shear measurements, because they enable to establish a correspondence between the steady-shear and the dynamic viscosity.

I. 3. Extension rates and the ink film splitting (tack measurements)

The flow in the nip region is particularly complex, since it is the result of a combination of shearing and extensional flows. Several studies have pointed on the fact that squeeze flow and fluid extension are the predominant modes of deformation of the ink as it passes through the nip [Lyne, 1989; Fu et al., 1994]. These authors even noticed that very little ink shearing occurs between the printing blanket and impression cylinders as they are driven by interlocked gears.

Extensional flow is of significant relevance in many practical situations, and its study is still evolving. Extensional viscosity (η_E) is a measure of the resistance of a fluid to extensional deformation (ε). Newtonian liquids have extensional viscosities exactly three times their shear viscosity : $\eta_E = 3\eta$, but in general, η_E is a function of the extensional strain rate ε, just as shear viscosity is a function of shear rate $\dot{\gamma}$. However this function is often qualitatively different from that of the shear viscosity. Thus, for example, shear-thinning elastic polymer solution exhibit frequently an extensional viscosity that increases dramatically with

strain rate [Barnes et al., 1989]. Extensional viscosity measurements are far more difficult to conduct than those related to shear experiments. To our knowledge, no standard technique for ink analysis exists up to now for this mode.

Given their shear-thinning and elastic nature, offset inks may be expected to display similar 'tension-thickening' behavior. As Lyne pointed out [1989], an attractive idea is to explore the similarity between the rise in storage modulus G' with increasing oscillatory shear rate (ω), and the rise of extensional viscosity with increasing extensional rate. He recognized however that the major distinction between the storage of elastic energy in oscillatory shear and in extensional flow is the magnitude of the absolute strain. In an oscillatory experiment (linear viscoelasticity), the samples are submitted to very small deformations with respect to their equilibrium position, while very large strain are usually encountered in extensional flow.

Tack may be interpreted as a manifestation of the extensional viscosity of offset inks. Zang et al. [1991] have defined the tack as the magnitude of the peak negative pressure at the exit of a nip which depends on both roller surface speed and fluid properties. The magnitude of this was between 0,2 and 0.4 10^3 Pa, at roller surface speeds of 236 and 690 feet/min, respectively, with ink film thicknesses in the nip of up to 15 μm. In most of the studies concerning the tack of printing inks, there is no clearcut correlation between tack and other rheological properties. It is generally assumed that the tack is strongly related to polymer structure and content in the ink.

I. 4. Viscosity/temperature relationships

During printing, whatever the process, the variations of viscosity - and other rheological properties - with temperature may affect the quality of the printed material. In offset for example, a temperature rise of 1°C produces a decrease of 10% in the ink viscosity. The consequences of this fall of viscosity are multiple, mostly a change in emulsification conditions, an increase in dot gain, and a modification of ink setting. The implications of temperature rise are even more dramatic in the case of waterless printing, since this process requires a stable high viscosity of the ink. However, few authors have reported quantitative studies of the extent of temperature/viscosity relationships. In this context, the theory of activation energy of flow correctly fits the data obtained from measurements carried out in the temperature range corresponding to

printing conditions (typically from 15 to 50°C). According to this theory, the viscosity dependence on temperature is:

$$\eta = A \exp(E_a / RT)$$

where A is a constant, Ea the activation energy of flow (kJ/mol.), T the temperature (K), and R = 8.314 J/mol.K.

Previous studies conducted in our laboratory produced E_a values for a large variety of inks [Blayo et al., 1996; Lanet et al., 1997]. In general, as expected, the larger the E_a value, the stronger is the temperature dependence of the ink viscosity.

However, care must be taken in the calculation of E_a for shear-thinning liquids like printing inks : the results strongly depend on the shear rate or stress at which the viscosity is taken. Thus, E_a should be considered as a shear rate function. Other rheological properties, such as the G' and G" moduli, also depend strongly on the temperature.

I. 5. Thixotropy, or the "ink history"

The shear history of the ink as it passes through the ink train is important in determining its flow behavior on the press. It is observed that the measurement of the rheological properties of inks are seldom stable and repeatable at shear rates below 100 s^{-1} [Lyne, 1989]. Thus, the shear history remains relevant as long as the ink structure is perturbed. Chou and Bain [1988] have quantified the thixotropy by the calculation of a thixotropy index, obtained from the up-and-down flow curves. This index is useful for the comparison of different inks, but it is very dependent on the experimental conditions under which it is obtained.

II. Some observations on the tack of offset inks

Ink formulations are generally based on several criteria, among which rheological properties play a major role: shear viscosity, yield stress, tack and, more and more often, viscoelastic parameters are the measurements generally used in this context. The inks must be conceived so as to fulfill the requirements of high press speeds, and the tack is one of the critical properties to control. Tack rises with an increase in the press speed, and this increase might become detrimental to the printing quality, since an ink with excessive tack can even pick the paper surface.

The increase in tack with roller speed can be explained by the extensional viscosity variations. Thus, a judicious choice of the vehicle formulation (gelling agent and/or "structured" resins) may limit this

phenomena. However, as mentionned above, no correlation exists between the tack and the ink properties. An attempt is made here to clarify this aspect.

II. 1. Ink samples

Three quickset inks (**A**, **B**, **C**) and their corresponding varnishes were analysed. These inks differed only by the nature of their phenolic-modified rosin resin (P-MRR) and by the amount of gelling agent introduced. Three resins of increasing molecular weight (resp. **A**, **B** and **C**) were used. Table 2 presents some of their characteristics. The resins **A**, **B** and **C** had a large molecular weight distribution (GPC). Resin **C** differs by its fraction of high molecular weight molecules. They had a cloudpoint in the Haltermann test oil 6/9 of about 100°C.

	Resin A	**Resin B**	**Resin C**
Mn	1 400	2 790	2 990
Mw	25 780	48 110	101 650
Mz	1 216 440	650 490	1 976 610
% resin > 500 000	3.5	3.6	***10.2***
Ip (= Mn /Mw)	18	17	34

Table 2 : Characteristics of the P-MRR A, B and C

Table 3 gives the composition of the inks A, B and C.

Ink type	Quickset **A**	Quickset **B**	Quickset **C**
Pigment	Blue (14 %)		
Phenolic Modified Rosin Resin	**Resin A**	**Resin B**	**Resin C**
Gelling agent (%)	***1.5***	***0.3***	-
Mineral oil type	28/31 and 6/9 (ratio 1/1)		
" Fat "	Alkyd resin (20 %)		
Drier combination	Co/Mn 10% metal (1/1) (2%)		

Table 3 : Compositions of inks A, B and C

Similarly, heatset model inks (1, 2, 3) and their corresponding varnishes were analysed. Again, these inks differed only by the nature of their P-MRR and by the amount of gelling agent introduced. Three resins of increasing molecular weights (resp. resins **1**, **2** and **3**) were used. They had a cloudpoint in the Haltermann test oil 6/9 of about 100°C. Table 4 presents some characteristics of the resins used in these heatset

formulations. The P-MRR had very similar IR and RMN spectra. They also had a large molecular weight distribution. Resins 1 and **2** had very similar molecular weights, whereas Resin 3 gave higher values and a wider distribution.

	Resin 1	**Resin 2**	**Resin 3**	**Hydrocarbon resin**
Mn	1 420	1 480	3 460	1 080
Mw	25 420	26 560	105 730	2 090
Mz	1 075 930	931 680	1 556 380	15 900
% resin > 500 000	3.5	3.5	*5.2*	0
Ip	18	18	31	2

Table 4 : Characteristics of the resins used in the corresponding heatset inks.

Table 5 gives the compositions of these inks.

Ink type	Heatset 1	Heatset 2	Heatset 3
Pigment	Blue (14 %)		
Phenolic Modified Rosin Resin	**Resin 1**	**Resin 2**	**Resin 3**
Co-resin (15%)	Hydrocarbon Resin (Fixed ratio PMR/HCR)		
Gelling agent (%)	*1.5*	*0.3*	-
Mineral oil type	4/7 and 6/9 (ratio 1/1)		
" Fat "	Linseed oil (10 %)		

Table 5: Compositions of heatset inks 1, 2 and 3

For the sake of comparison,other samples were also analysed, namely a coldset black ink, and three other commercial quickset inks I, J and K.

II. 2. Rheological characterization

Flow properties

The steady shear flow analysises of the ink and varnish samples were conducted on a rotating rheometer (TA Instr. CSL^2_{500}), with the cone-plate geometry (diameter = 2 cm, top angle = 4°). Controlled-stress flows were performed from 0 to 2000 Pa, during 4 min., at different constant temperatures (10 to 40°C).

Viscoelastic behavior

• The oscillatory flow experiments were conducted on the same cone-plate rheometer, within the appropriate stress and frequency ranges. Preliminary experiments were performed in order to establish the linear viscoelasticity domain. Oscillation frequencies were scanned in a logarithmic mode, from 0,1 to 20 Hz, at different constant temperatures (10 to 40°C).

• In addition to the dynamic measurements on the rotating rheometer, viscoelastic properties of the samples were measured on a Metravib viscoanalyser. This equipment was described in a previous study [Blayo *et al*, 1996]. All the experiments were performed in the annular shearing mode. The temperature was kept constant (20 or 30°C) and 8 frequencies were scanned, from 7.8 to 500 Hz, at each temperature.

Tack measurements

The tack of the varnishes was measured with a Tack-o-Scope device. Experiments were carried out, using samples of 0.6 cm^3, with rotating speeds varying from 50 to 350 m/min, at 20°C and 30°C.

II. 3. Results

As expected, the quickset and heatset samples presented a shear-thinning behavior in the range of shear rates and temperatures examined. The power-law gave a good description of this behavior. The values of the activation energy of flow (Table 6) were similar, but relatively high.

	Ea (±5 kJ/mol)
Ink A	114
Ink B	120
Ink C	114
Ink 1	122
Ink 2	115
Ink 3	125

Table 6: Activation energies of flow of ink samples

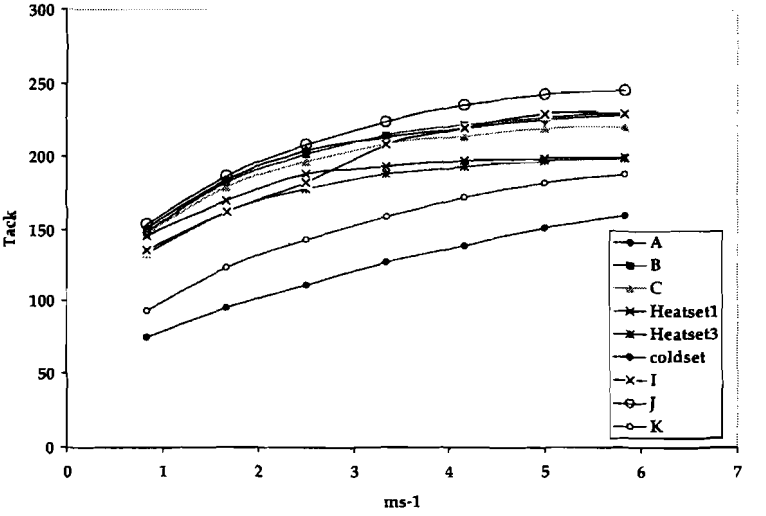

Figure 2: Variation of tack with the speed of the rollers of the Tack-o-Scope (20°C)

Figure 2 presents the variations in the tack of the samples as a function of the Tack-o-Scope speed. For the sake of comparison, the analogous variations for the additional samples are shown. Similar curves were obtained by Oittinen [1976], with different model inks.

The common pattern of these curves suggests that the dependence of the tack on roller speed can probably be represented by a general model, characterized by the following features:

- One can expect the existence of an asymptotic value of tack as the roller speed becomes very high. This value is probably related to the cohesive energy of the ink, i.e. the force necessary to split a viscoelastic liquid at a very high strain rate is likely to be related to its internal cohesion.

- The curve can reach its asymptotic value for small or large values of the roller speed, depending on the viscoelastic properties of the ink, which in turn depend essentially on the polymer properties.

- When the roller speed tends to zero, the tack value is likely to reflect the viscous flow at very low strain rate and could be considered

as the counterpart of the limiting value of η_E when ε tends to zero. It should therefore show the same variations as η_0 and/or η_E.

Given these assumptions, a relationship between the tack and the roller speed can be tentatively proposed, namely :

$$\tau = \tau_\infty - (\tau_\infty - \tau_0)\exp(-\alpha v) \qquad (1)$$

where τ is the tack value measured at the speed v ($m.s^{-1}$),
τ_∞ is the 'asymptotic' value of the tack, maximum value,
τ_0 is the tack value when v tends to zero, minimum value
and α is the inverse of a characteristic velocity.

These three parameters were estimated using the data obtained in this work. In this first approach, τ_∞ was estimated directly from the curve, whereas α and τ_0 were calculated by a least squares method. Table 7 sums up these results.

Sample	τ_∞	τ_0	α
Ink A	238	123	0.44
Ink B	240	118	0.45
Ink C	225	96	0.61
Heatset 1	205	130	0,50
Heatset 3	202	87	0,62
Coldset	200	46	0,23
I	240	60	0,52
J	260	113	0,42
K	200	48	0,43

Table 7: Constants of equation (1) for various inks

II.4. Discussion

Influence of the resin on the tack- vs.- speed behavior of inks A, B, C, 1 and 3.

The values of α for samples A and B are similar. In fact, based on their compositions, one could have expected close properties. On the contrary, the variations of the tack vs. speed of sample C differ appreciably. The asymptotic value of tack for ink C seems to be reached at lower speeds than those related to inks A and B. The vehicle composition of this sample may explain this feature, namely a higher content of high-molecular weight polymers, a larger Ip value, hence a pronounced non-

newtonian behavior. These observations are confirmed by Figure 3 which shows the variations of the elastic modulus G′ and the dynamic viscosity η′, as a function of the frequency. A and B displayed similar trends, whereas C had different viscoelastic characteristics.

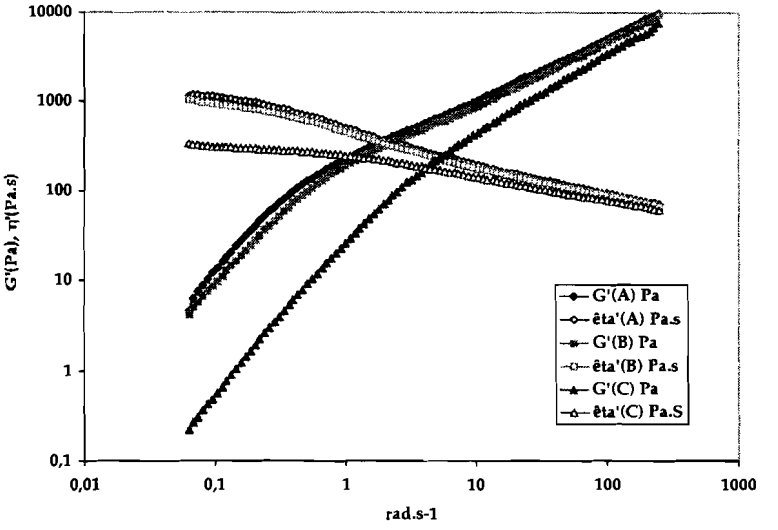

Figure 3: Variations of G′ and η′ vs. angular frequency (ω) of inks A, B and C (20°C)

The variations of the shear viscosities of the same samples confirmed the assumption that τ_0 can be related to the zero-shear rate viscosity: Table 8 gives the values of the viscosity (20°), extrapolated at very low shear rates, and the corresponding τ_0 values. Similar tendencies were observed with the heatset ink **1** and **3** (inks **1** and **2** had also close properties, similarly to inks **A** and **B**).

	τ_0	η_0 (Pa.s)
A	123	≈ 1500
B	118	≈ 1300
C	96	≈ 1000

Table 8: τ_0 and η_0 values at 20°C, for inks A, B and C

Influence of the ink type on the tack evolution

For the sake of comparison, the tack-speed curves of some commercial inks, whose compositions were not known, were also analyzed (see Figure 2). The α values obtained for the quickset inks (A, B, C, I, J and K) were rather close ($\approx$ 0.4 to 0.6), whereas the coldset ink possesses smaller α value (0.23), which could be characteristic of the rheological behavior of a near-newtonian ink. In the same way, the viscosity of the coldset ink was much smaller than those of sheetfed quickset inks, which implies a lower τ_0 parameter.

Particular case of newtonian and 'nearly-newtonian' liquids

The tack of different ink components was also investigated in the past. For example, Oittinen [1976] plotted the tack-speed relationships for a great variety of ink components and model inks, for speed varying from 1 to 4 $m.s^{-1}$. The measurements were also conducted on a Tack-o-Scope. In this study, some samples were considered as newtonian liquids, in the range of shear rates investigated. Straight lines were obtained. This situation can be described adequately by equation (1). It was previously assumed that α is related to the elastic properties of the ink, and decreases as the behavior approaches a newtonian one. Thus, for a newtonian or nearly newtonian liquid, α should be very small, making the term αv also small. In these conditions, $\exp(-\alpha v)$ can be approximated by $(1 - \alpha v)$ and equation (1) becomes:

$$\tau = \tau_0 + (\tau_\infty - \tau_0)\,\alpha v \qquad (2)$$

Equation 2 is coherent with the linear tendencies reported by Oittinen. Moreover, she observed that the tack of her samples, measured at a given speed, varied linearly with their shear viscosity, which confirms the significance of τ_0.

Additional comment

At a given constant press speed v, when the ink passes the printing nip, it is submitted to a controlled-rate extensional strain ε'. At a given position x in the nip (after the center of the nip), the extensional strain rate $\varepsilon'(x)$ is necessarily a function of the roller speed, the roller diameters and the thickness of the ink film. In fact, a simplified calculation of $\varepsilon'(x)$ gives an expression showing a simple relationship between $\varepsilon'(x)$ and v. Moreover, it introduces in equation (1) the other parameters which affect

the ink tack. Having reached thus far, we feel this first approach appears reasonable, but requires further improvement, since it does not take into account, among other thing, the roller deformation.

Conclusion

Ink behavior on a press depends on many properties, which were described in the first part of this paper. These include the shear viscosity and the flow behavior of the ink, its viscoelastic character, the sensitivity of these properties on temperature variations, its shear history, and finally its extensional flow behavior. The latter is perhaps the most difficult parameter to evaluate, but it is also one of the most pertinent in relation to the passage of the ink in the printing nip. Tack measurements, which are largely used in printing ink control, can be considered as an alternative way to express the extensional viscosity. From these, an empirical relationship between tack values and roller speed was proposed. This equation takes into account the different parameters which are usually known to affect the ink tack. This novel approach is under closer experimental and theoretical scrutiny.

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