Rheological Testing of Xerographic Liquid Inks: A Need for Printing Technology

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Abstract:
Rheological properties of xerographic liquid inks of different concentrations of solid particles have been tested. Generally we have found that viscosity decreases with increasing shear rate, i.e. the system is pseudoplastic as corresponds to the break down of aggregated particles by the applied shear. The viscosity of inks may vary in orders of magnitude depending on solids concentration, reaching up values of ~ 10^8 Pas for solids concentration of 40 wt%. The existence of a yield critical stress has been discussed and we estimate that it increases exponentially with solids concentration. We have looked for possible differences in the rheological behavior of ink samples obtained either diluting more concentrated inks or drying less concentrated ones. Concentration and dilution of xerographic inks do not change their rheological properties meaning that the microscopic structure of the concentrated dispersion is broken (when diluting) and recovered (when drying) reversibly. On the other hand processed ink (previously subjected to high mechanical and electrostatic stresses) behaves differently than non-processed ink. The properties of processed inks are not totally recovered when diluting, manifesting itself in a higher effective apparent viscosity. This result should be of main concern to liquid ink based printing technologies, for which elimination of waste by recycling processed ink is a major goal.

Zusammenfassung:
Rheologische Eigenschaften von Xerographischen Flüssigtinten verschiedener Konzentrationen an Feststoffteilchen wurden getestet. Im Allgemeinen haben wir festgestellt, dass die Viskosität mit ansteigender Scherrate abnimmt, d. h. das System ist pseudoplastich was einem Abbau der aggregierten Partikel durch die angelegte Scherung gleichkommt. Die Viskosität der Tinten kann über mehrere Groessenordnungen varieren, abhängig von der Feststoffkonzentration kann sie einen Wert von ca. 108Pas für eine Feststoffkonzentration von 40gew% erreichen. Die Existenz einer Fliessgrenze wurde diskutiert und wir liefern eine Abschätzung, dass sie exponentiell mit der Feststoffkonzentration anwächst. Wir haben nach moeglichen Unterschieden im rheologischen Verhalten von Tintenproben Ausschau gehalten, die entweder durch Verdünnung konzentrierterer Tinten oder durch Trocknung weniger konzentrierter Proben erhalten wurden. Aufkonzentrierung und Verdünnung xerographischer Tinten verändern nicht deren rheologische Eigenschaften, was bedeutet, dass die mikroskopische Struktur der konzentrierten Dispersion zusammenbricht (bei Verdünnung) und reversibel wiedererlangt wird (bei Trocknung). Andererseits verhält sich verbrauchte Tinte (welche vorher hohen mechanischen und elektrostatischen Spannungen unterzogen wurde) anders als unverbrauchte Tinte. Die Eigenschaften verbrauchter Tinte werden durch Verdünnung nicht vollständig widererlangt, was sich in einer hoeheren effektiven scheinbaren Viskosität zeigt. Dieses Ergebnis sollte für Drucktechnologien, welche auf flüssiger Tinte beruhen und für die die Entsorgung von Abfallstoffen durch recyclieren verbrauchter Tinte ein wichtiges Ziel ist, von groesserem Interesse sein.

Résumé:
Les propriétés rhéologiques d'encres liquides xérographiques, contenant différentes concentrations en particules solides ont été étudiées. Généralement, nous avons trouvé que la viscosité décroîssait quand la vitesse de cisaillement croîssait, c-à-d, le système est pseudoplastique, puisqu'il correspond à la rupture des agrégats de particules par l'application du cisaillement. La viscosité des encres peut montrer des variations de plusieurs ordres de magnitude pour différentes concentrations en solides, jusqu'à atteindre des valeurs de 108Pa.s pour une concentration en solide de 40% en poids. L'existence d'une contrainte seuil a été discutée et nous estimons que celle-ci augmente exponentiellement avec la concentration en solides. Nous avons recherché des différences possibles dans le comportement rhéologique entre des encres obtenues soit en diluant des échantillons plus concentrés, ou en sèchant des échantillons moins concentrés. Une concentration ou une dilution des encres xérographiques ne change pas leurs propriétés rhéologiques, ce qui implique que la structure microscopique de la dispersion concentrée est cassée (lorque diluée) et recouvrée (lorsque séchée) réversiblement. D'autre part, l'encre mise en oeuvre manuellement (précédemment soumise à de fortes contraintes mécaniques et électrostatiques) se comporte différemment des encres non mises en oeuvre. Les propriétés des encres pré-traitées ne sont pas totalement recouvrées lorsqu'elles sont diluées, ce qui se révèle par une viscosité apparente effective plus élevée. Ce résultat devrait être de grande importance pour les technologies d'impression à base d'encre liquide, pour lesquelles l'élimination des dêchets au moyen du recyclage de l'encre mise en oeuvre est un objectif majeur.

Key words: xerographic inks, printing technology, pseudoplasticity, aggregation, yield stress

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a fluid-like state increases exponentially with the solids concentration of the ink.

6 COMPARISON OF PROCESSED AND NON-PROCESSED SAMPLES

We have studied the influence of the use of toner inks in practical conditions to their rheological properties. A sample of ink was subjected to a process similar to that it experiences during the xerographic process. An ink film, of about 5 wt% solids, is formed on a rotating drum, the ink is charged, mitered, conditioned and scrapped. The ink film is subjected to mechanical and electrical stresses. This process was carried out at Xerox Wilson Center for Research and Technology by technical staff belonging to Xerox. The machine where the process was conducted is designed to emulate the stresses the ink is going to suffer under the xerographic process. The final paste has a concentration of about 23.5 wt%. In what follows we will refer to this ink as “processed ink”. We prepared two samples: one of 23.5 wt%, as received, and another one diluting the processed 23.5 wt% ink down to a 13.5 wt%. Additionally, we prepared two samples of the same concentration from a non-processed ink.

Our goal was to check if the reversibility shown for CEP inks equally exists for processed inks. Fig. 8 shows the flow curves for the four samples. The rheology tests showed the irreversibility of the processed ink. Whereas the flow curves are indistinguishable for processed and non-processed 23.5 wt% ink, the diluted processed ink shows higher viscosity than the 13.5 wt% non-processed ink. If we represent shear viscosity versus shear stress, we see that the diluted sample from the processed ink has a higher value of the yield critical stress (Fig. 8 inset). Figure 9 shows a picture form the optical microscope of a diluted sample of processed ink after being mechanically sheared. It can be seen that, in spite of the strong shear applied, ~10 μm sized aggregates persist that cannot be fully destroyed. It is therefore plausible that during the conditioning process the stresses applied to the ink enhance interparticle adhesion and this may be the reason for the higher viscosity measured for the diluted processed ink. The increase of interparticle adhesive forces with the applied

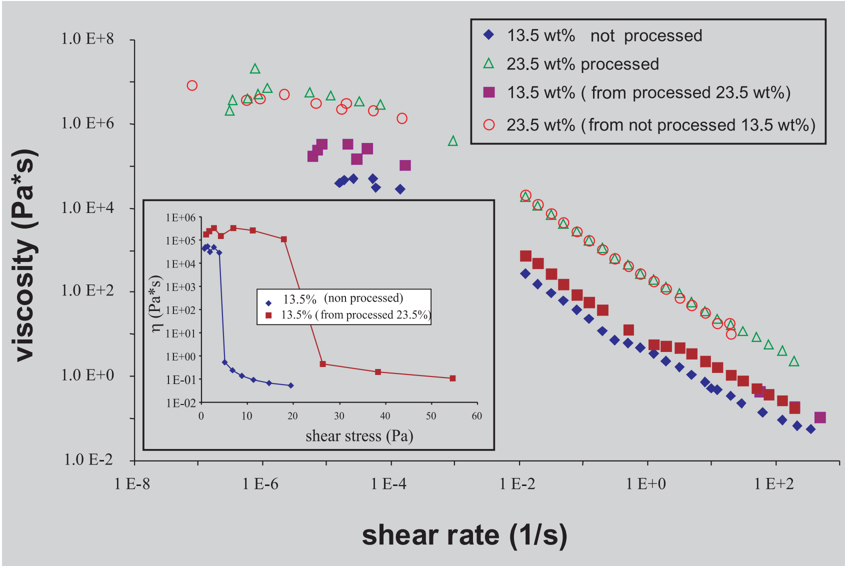

Figure 8 (above): Ink viscosity as a function of the shear stress for several xerographic inks obtained from processed and non processed samples as indicated. The inset shows the increase of yield critical stress when the diluted sample comes from a processed ink.

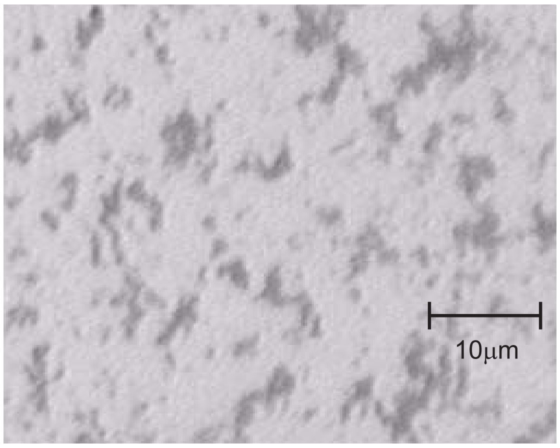

Figure 9 (below): Picture taken from the optical microscope of processed ink after being strongly sheared shows the persistence of particle aggregates.

load, even by some orders of magnitude, is a well known phenomenon for fine powders [7].

7 CONCLUSION

We have measured the shear-dependent rheological properties of xerographic liquid inks for shear rates ranging from 10^{-7} to 10^{3} s^{-1} and solids concentrations ranging from 13 to 40 wt%. The flow curves (viscosity versus shear rate) reveal pseudoplastic behavior and are well described by a simple Ostwald-de-Waele model. We give the evolution of the fitting parameters with ink concentration.

Inks do not show different behaviors whether the samples are obtained through diluting more concentrated inks or drying less concentrated ink. From this point of view, drying and diluting of inks is a reversible process. However, samples processed in a device that simulates the real conditions in a printer or copier do not recover their original behavior when diluted. The samples obtained from diluted processed samples show a higher viscosity and a higher yield critical stress. According to visual inspection of pictures

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from the optical microscope this behavior could be related to the irreversible increase of interparticle adhesive forces by the strong shear and electric stresses previously applied in the conditioning process.

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