CHARACTERISATION OF CERAMIC FRIT-BASED INKJET INKS BY OPTICAL RHEOMETRY AT HIGH SHEAR RATES

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1. INTRODUCTION

The inkjet inks used in ceramics must display appropriate rheology for optimum printhead printing operation. The influence of the rheological properties of a liquid and its ability to form well-defined drops in inkjet printing, with few or no satellite drops, is currently determined by characterising ink viscosity, surface tension, and stability. Ink viscosity must be low and constant at inkjet printhead working temperature (in the 10 to 25 mPa·s range), as ink printability (characterised by the Ohnesorge number) depends on the **viscosity** and surface forces of the fluid. In printheads, the shear stress to which the ink is subjected is high (reaching rates over $10^4 s^{-1}$), so that determining viscosity at these rates without having to extrapolate the values requires using an instrument other than the rotational rheometer. The measurement of rheological behaviour at high shear rates by an optical rheometer is a recent technique, as inkjet ink shear viscosity is customarily measured with a controlled-stress rotational rheometer, the shear stress that can be applied in these types of rheometers being limited by the maximum stress and measurement error obtained at shear rates over $10^2 s^{-1}$ due to sample centrifugation (Taylor vortices).

In this study, four types of inkjet inks or digital application products were characterised, evaluating the effect of the type and percentage of dispersant additive used on viscosity at high shear rates (measured in an optical rheometer) and ink printability.

2. EXPERIMENTAL

2.1. DETERMINATION OF VISCOSITY AT HIGH SHEAR RATES OF THE INKJET INKS OR DIGITAL APPLICATION PRODUCTS DEVELOPED

This study sets out the results obtained with the optical rheometer FLUIDICAM-RHEO supplied by the company Formulaction. This optical rheometer provides viscosity analysis thanks to sample flow visualisation in a microfluidic channel at the set test temperature, yielding the evolution of viscosity at high shear rates. To characterise the digital products made, two types of channels (GAP of 50 and GAP of 150) were used, shown in Figure 1, which allowed maximum shear rates of $4·10^4 s^{-1}$ to be attained. The viscosity tests were performed at three working temperatures (25, 40, and 50ºC), the results being compared with those obtained in a Brookfield-type viscometer.

The viscosity measurement at high shear rates enabled calculation of the Ohnesorge modulus for assessment of the theoretical printability and verification of the behaviour of the glazes developed with different additives.

2.2. DETERMINATION OF THE THEORETICAL PRINTABILITY OF INKJET INKS OR DIGITAL PRODUCTS

In order to characterise the behaviour of the formulated suspensions, three dimensionless moduli, defined by I. Hutchings in his study on the behaviour of liquids in inkjet printheads were used: Reynolds number (Re: ratio of the inertial forces to the viscous forces), Weber number (We: ratio of the kinetic forces to the surface forces), and Ohnesorge number (Oh: ratio of the viscous forces to the surface forces). These moduli and the characteristic parameters of the printing system considered (DOD) enabled the appropriateness of the additive used in the glaze for inkjet printing systems to be determined.

2.3. DEVELOPMENT OF PRINTING PATTERNS BY MEANS OF INK-TESTER

The application method consisted of inkjet printing of the developed suspensions using a laboratory INK-TESTER instrument equipped with a SEIKO 1536-L industrial printhead, Figure 1 (right). Regulating the electric pulses of the piezoelectric system, the instrument provided different g/m^2 laydowns of the suspension, yielding a continuous, uniform layer to enable assessment of the technical and aesthetic properties of the decorations developed with the different types of dispersant additives.

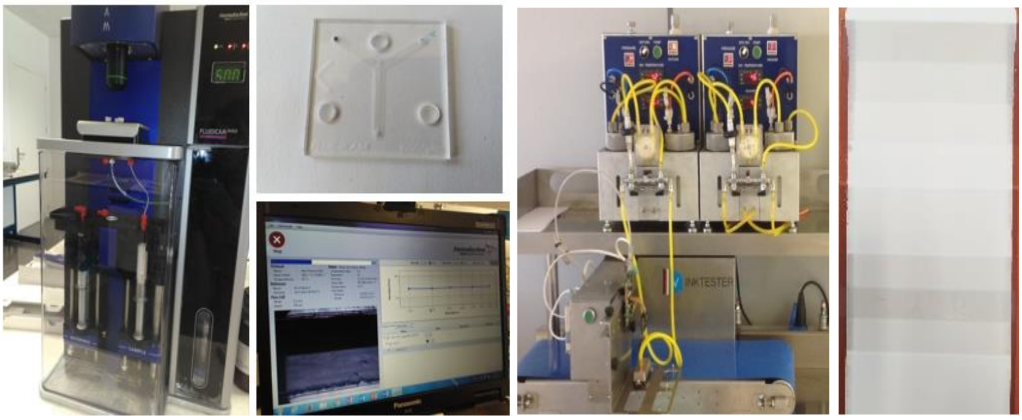

Figure 1. *Optical rheometer for measuring viscosity at high shear rates (left). Ink-tester used in preparing the printing patterns of the developed digital inkjet formulations (right).*

3. RESULTS AND CONCLUSIONS

A method has been fine-tuned in this study for assessing the appropriateness of digital products formulated at laboratory level for use in inkjet printheads based on characterisation of their rheological behaviour at high shear rates and their printability. The method has allowed objective selection of the optimum suspensions for subsequent use in inkjet systems, or rejection, at laboratory level before scaling up suspension development at industrial level.

In accordance with the results obtained in the printability study, which enabled the optimum percentages of the additives used to be established, it may be concluded that the dispersants characterised were suitable for digital glaze preparation and subsequent use in inkjet printheads.

4. REFERENCES

[1] Hutchings, I. Ink-jet printing in micro-manufacturing: opportunities and limitations. Institute for Manufacturing, Department of Engineering, University of Cambridge, Cambridge CB3 0FS, UK

[2] Berby, B. Inkjet printing of Functional and Structural Materials: Fluid Property Requirements, Feature Stability and Resolution. Annual Review of Materials Research. 2010. 40:14.1-14.20.