INFLUENCE OF THE KAOLIN IN THE SUBSTRATE ON THE QUALITY OF INKJET PRINTING

Luc Bourgy – Alexandre Barreau [(1)], Cedric Poilly [(2)]

[(1)] Imerys Ceramics Technologies UK, Newton Abbot, UK

[(2)] Imerys Ceramics France – Ceramic Centre. Limoges, France

ABSTRACT

With a view to maintaining the high quality of ceramic inkjet print on a substrate after firing, the choice of the kaolin introduced in the substrate formula is key. In this paper, we show how the printability of a ceramic substrate can be modified by the kaolin characteristics. Particle size distribution, shape factor, and chemical analysis influence the suction behaviour, the colour development and the substrate aspect after firing.

1. INTRODUCTION

For many years, Imerys has acquired knowledge and expertise in developing kaolin and mineral formulas for the paper industry and specifically paper coatings for printing[1]. The aim of this study is to investigate experimental methods to characterize the ceramic substrates and kaolins to determine the parameters influencing the inkjet printings results.

Kaolin is a minor component in weight in the substrate formula but due to its Particle Size Distribution, it becomes a major one, accounting for 25% to 45% of the fine particles smaller than 2 µm.

This study focuses on the role of kaolin in an inkjet printing substrate. Different kaolin types have been selected according to their characteristics to determine their influence on the print quality.

2. TESTING CONDITIONS

The substrates preparation, firing, and printing as well as the determination of the influence of the kaolin on colour development, were performed in collaboration with the Instituto de Tecnología Cerámica (ITC) of Castellón, Spain.

A standard opaque glaze substrate recipe was prepared with the different kaolins. The substrate is composed of 90% opaque frit and 10% kaolin, by weight. In addition 0.3% sodium carboxymethylcellulose (CMC) and 0.3% Sodium Tripolyphosphate (Na-TPP), by weight, were introduced relative to the solid.

The suspensions were prepared by wet milling in a fast laboratory mill using alumina grinding media. The glazes were characterized and presented the same particle size distribution.

Each suspension was applied on fired wall tile with engobe, using a glaze applicator with an aperture of about 600 µm to obtain a homogeneous layer.

Commercial ceramic inks were applied on the substrate by an Efi – Cretaprint printer. The dot sizes and colour developments were analysed after firing.

3. CHARACTERISTICS OF THE KAOLINS

The kaolins were commercial grades and are already used in glaze formulations. Their chemical analyses (Table 1), determined by glass disc XRF, show different levels of purity in terms of aluminium oxide, potassium oxide and chromophore oxide contents.

	FJK 1	FJK 2	FJK 3	FJK 4	FJK 5	FJK 6	FJK 7	FJK 8
Al_2O_3 (%)	35.35	37.57	34.55	38.18	36.64	35.88	35.20	33.04
$Fe_2O_3 + TiO_2$ (%)	1.05	0.98	0.97	0.96	1.02	0.38	1.06	2.08
K2O (%)	2.47	1.20	1.09	0.31	2.38	0.01	3.16	2.11
LOI (%)	11.20	12.77	12.24	14.27	11.60	14.02	10.99	12.50

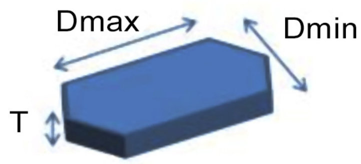
Table 1: Chemical analysis measured by glass disc XRF.

The tested kaolins presented a wide range of Particle Size Distribution measured by Sedigraph (Table 2). To characterize the fineness of the kaolin, the amount of particles finer than 2 µm and the steepness of the Particle Size distribution related to the Span of the distribution were considered.

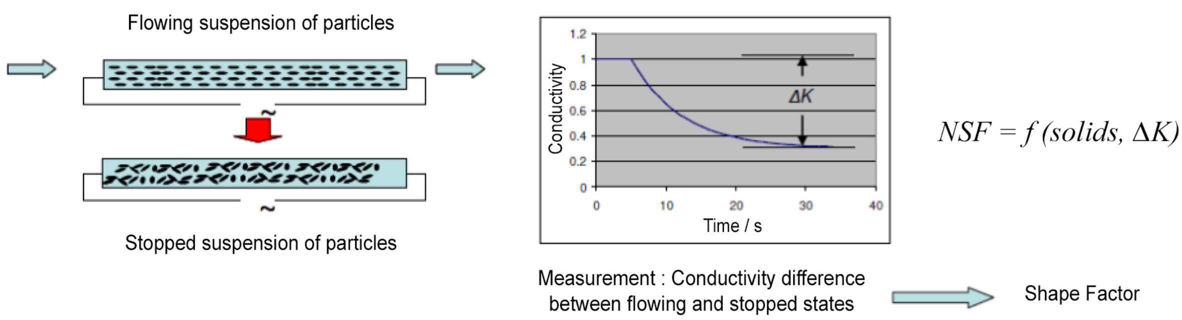
$$\text{Span} = \frac{D90 - D10}{D50}$$

The New Shape Factor characterizes the shape of the kaolin particles. It is the average ratio of a particle length to its thickness.

$$NSF = \frac{Dmax + Dmin}{2T}$$



The NSF was measured with the Panacea instrument (Particle Assessment by Natural Alignment and Conductivity Effect Analysis), which has been specifically developed to characterize the shape of the kaolin particles.

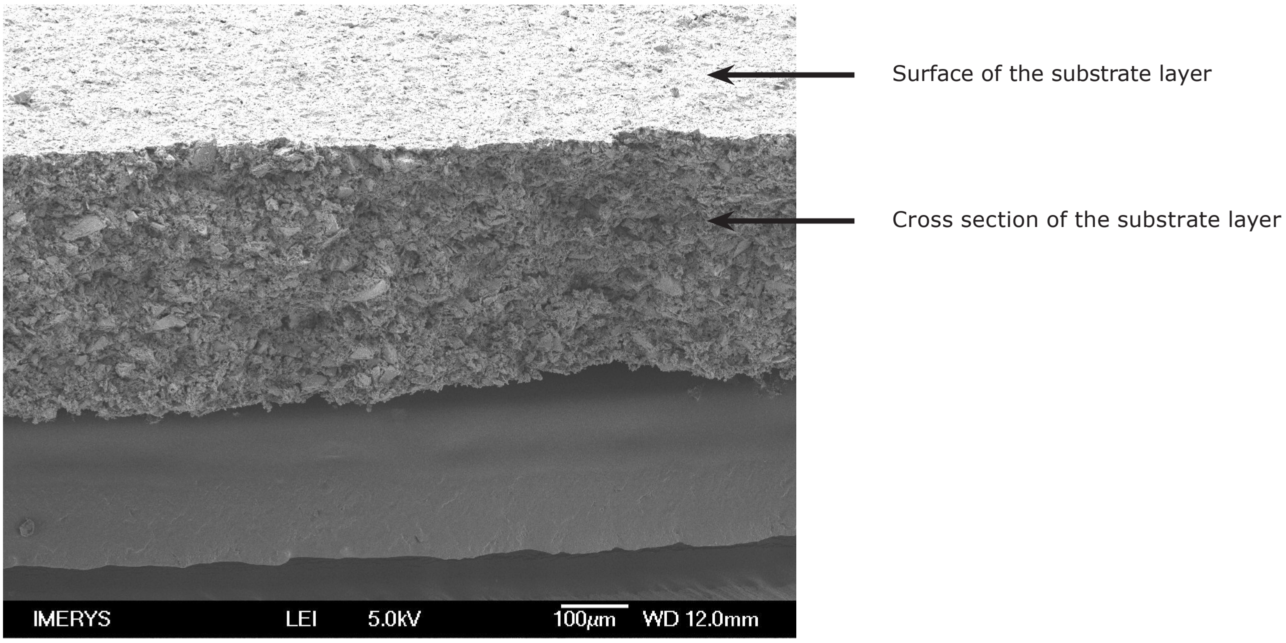


	FJK 1	FJK 2	FJK 3	FJK 4	FJK 5	FJK 6	FJK 7	FJK 8
%<2µm	54	56	52	71	38	93	51	80
D90 (µm)	10.50	7.75	9.27	6.30	12.39	1.18	5.71	3.96
D50 (µm)	1.68	1.46	1.80	0.47	3.54	0.38	1.96	0.42
D10 (µm)	0.24	0.24	0.24	0.21	0.32	0.21	0.40	0.21
Amplitud	6.1	5.2	5.0	12.9	3.4	2.6	2.7	8.9
NSF Panacea	34	25	23	5	18	4	27	13

Table 2: Particle Size Distribution and Shape Factor index.

4. CHARACTERISTICS OF THE SUBSTRATE

The surface of the substrate was observed by Secondary Electron Microscope (SEM). The kaolin particles represent 10% by weight of the substrate composition. Due to their morphology and size, the kaolin particles build a porous structure on the surface of the substrate. They tend to orientate horizontally when the NSF is high. The SEM images below show the structure difference between the surface and inside the substrate layer.



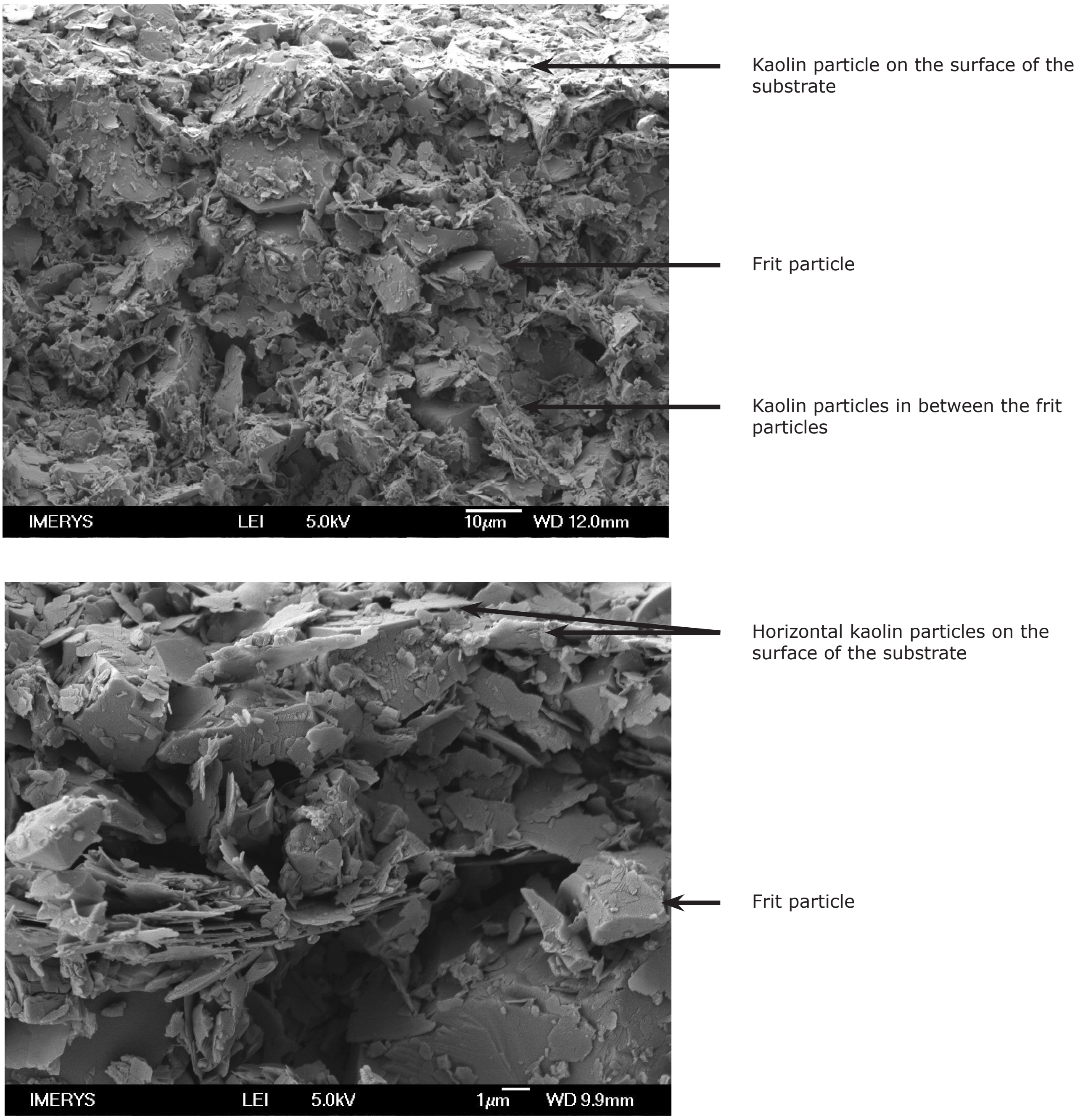


Image 1, 2 and 3: Details from the substrate made with the FJK1 kaolin.

5. SUBSTRATE-CERAMIC INK INTERACTION

The arrangement of the kaolin particles creates a porous structure.

A Fibrodat instrument was used to observe the influence of this porosity on the ceramic ink absorption (Image 4). The drops generated are 100 times bigger than those produced by an inkjet head printer, but some of the behaviours can be extrapolated.

The contact angle, the spreading behaviour and the absorption time of the ink on the substrates were recorded.

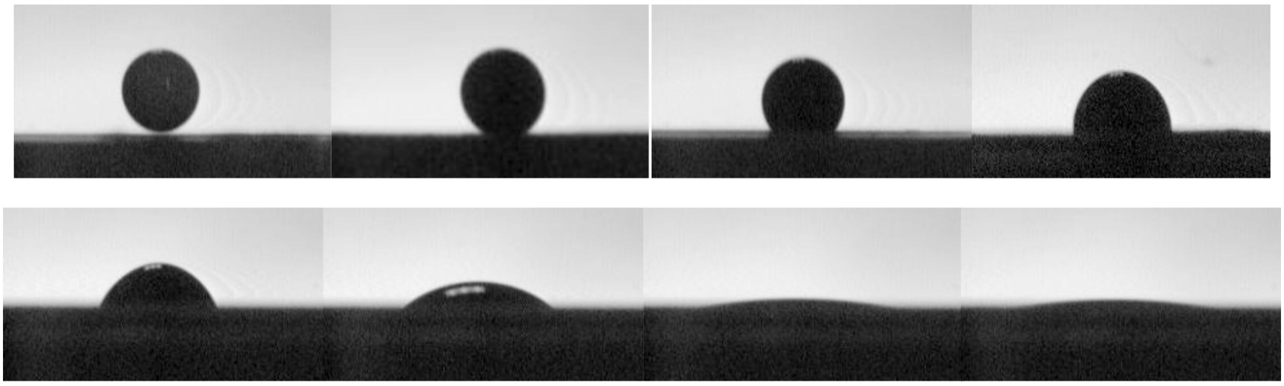
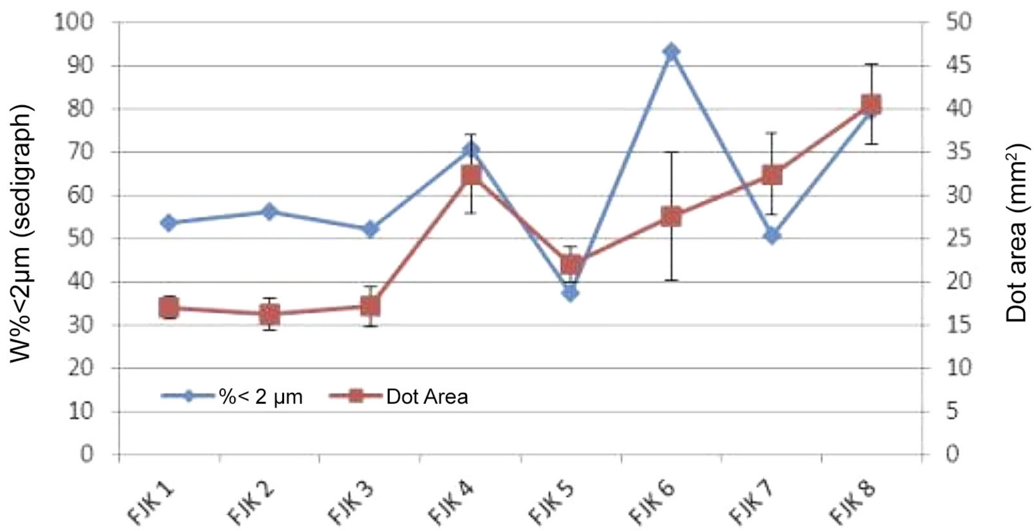


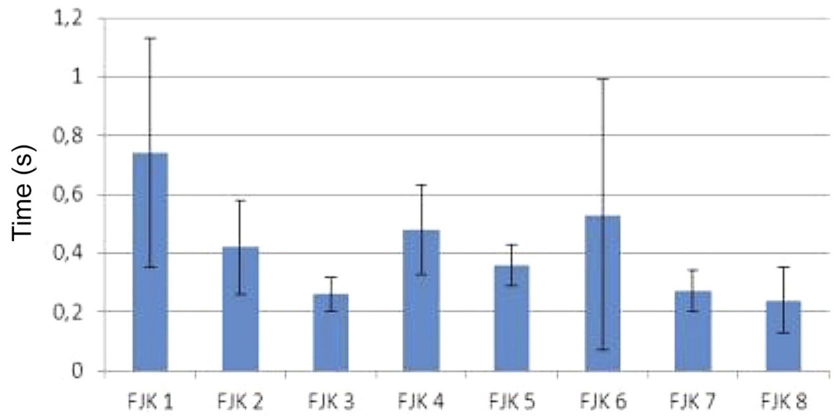
Image 4: Ceramic ink drop dropping on the substrate.

The size of the printed dots was measured and related to the fineness of the kaolins (Graph 1). The PSD seems to be one of the key parameters determining the spreading behaviour. The finer kaolins present a higher standard deviation of the printed area. The sample FJK6 does not follow this trend.



Graph 1: Relation between the printed area and the percentage of the particles smaller than 2 μm in the kaolins.

The absorption time recorded illustrates the suction behaviour of the substrate. The suction depends on the porous structure built during the substrate application. It depends on the particle packing (PSD, Shape factor and Span). The absorption time is high when the kaolin particles are fine and/or present a high shape factor (FJK1, FJK6 substrates). The absorption time tends to be low when the particles are blocky, coarse and present a high Span.



Graph 2: Absorption time of the brown ink drops on the substrate.

6. AFTER FIRING CHARACTERISTICS

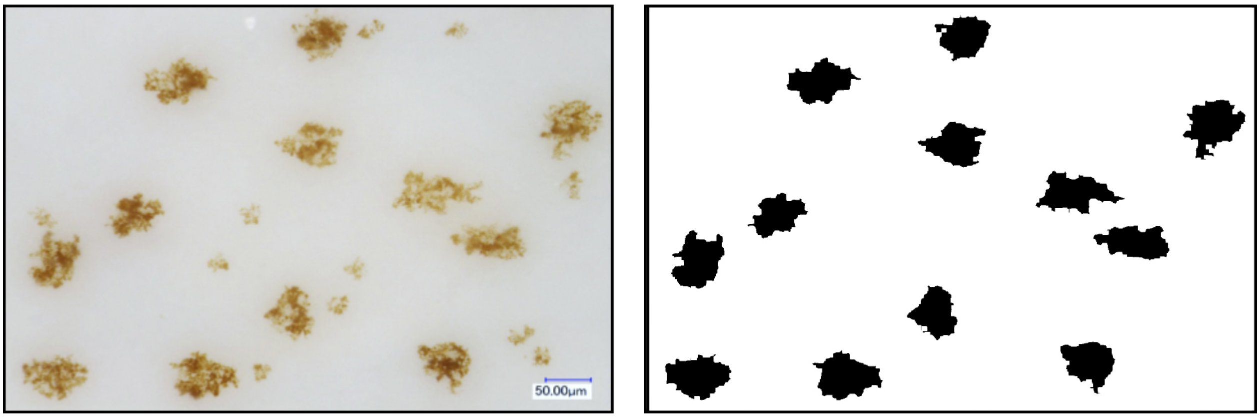
The tiles were printed with an industrial digital inkjet printer. The print pattern was designed for 3 coloured inks at different grey levels (Image 5).

Once fired, the colour developments the printed areas and the surface aspects were measured.

Image 5: Digital inkjet printed patterns.

PRINTED AREAS

The drop sizes and the standard deviation were optically observed with a digital microscope. The images of individual printed dots were collected for the brown ink at 10% grey level (Image 6).

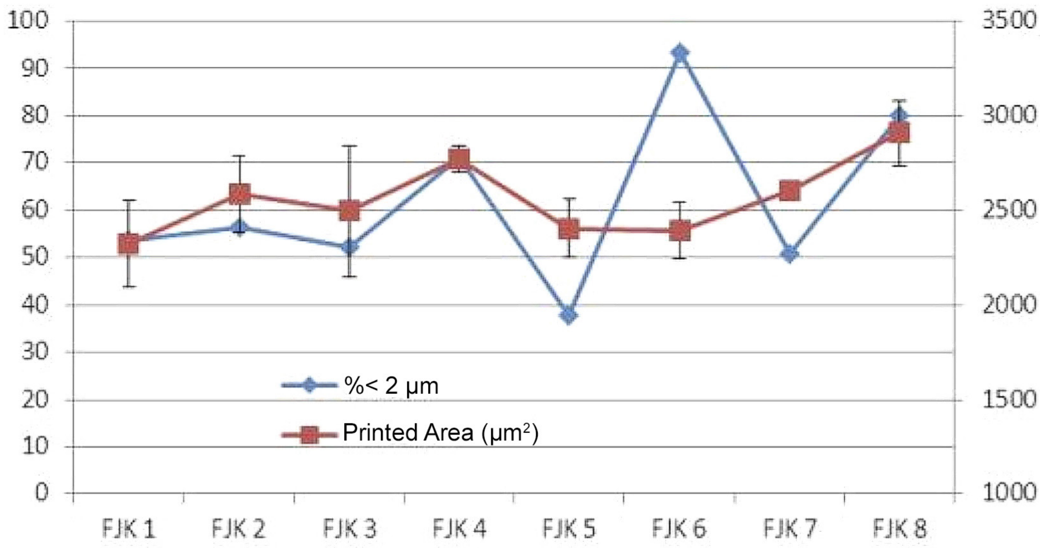


Original image

Image J used to analyse image and calculate individual dot areas (ignore smaller dots)

Image 6: Printed drop size analysis.

The printed area is related to the kaolin characteristics. The PSD seems to be one of the key parameter influencing the printed dot size (Graph 3). The kaolin FJK6 does not follow this trend.

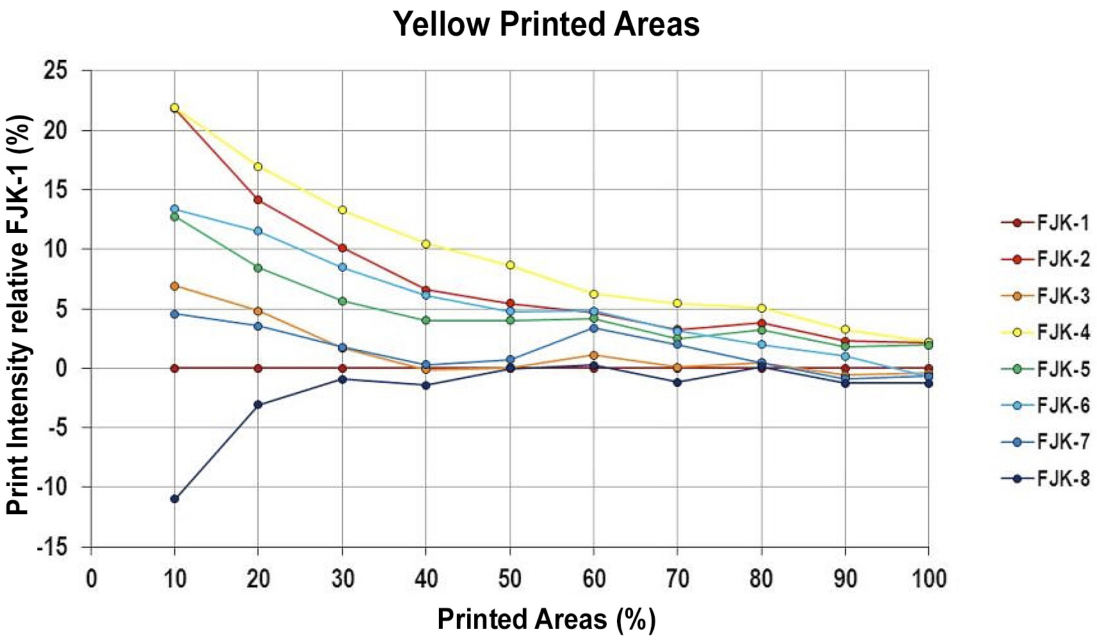


Graph 3: Relation between the printed area after firing and the percentage of the particles smaller than 2 µm in the kaolin.

The printed area obtained by the industrial digital inkjet printer after firing presents the same behaviour as the spreading profile of the inks measured with the Fibrodat.

COLOUR DEVELOPMENT

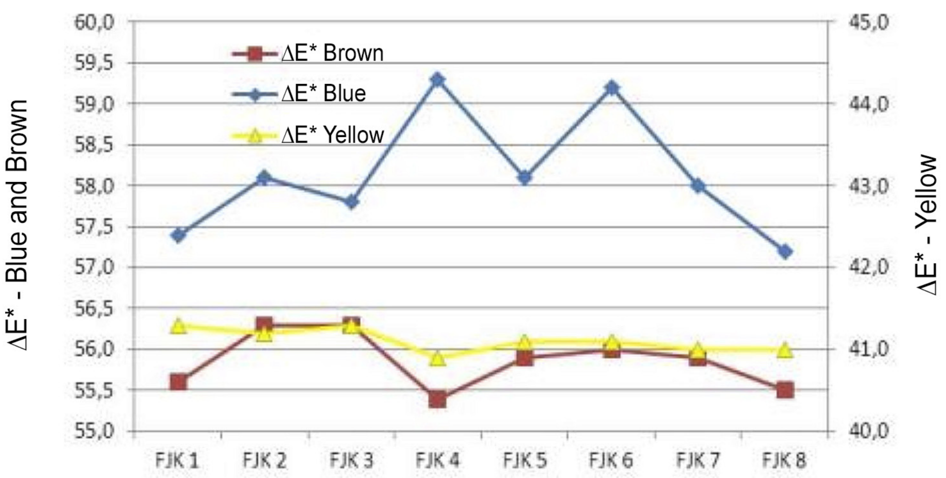
The colour of the printed substrate at each grey level was measured with a colorimeter. At low grey levels, the differences are significant and usually related to the chromophore oxides / alumina ratio in the kaolin.



Graph 4: Yellow intensity of the yellow printed colour at different grey levels.

To determine the influence of the kaolin on the ink colour development, the difference between the colour of the substrate and the printed substrate (100% printed area) is measured (Graph 5).

The kaolin FJK4 allows better development of the Blue colour but is detrimental to the Yellow and Brown colours. The kaolin FJK6 develops the Blue better. The FJK2 and FJK7 present a balanced behaviour, not enhancing one colour in detriment to the others.



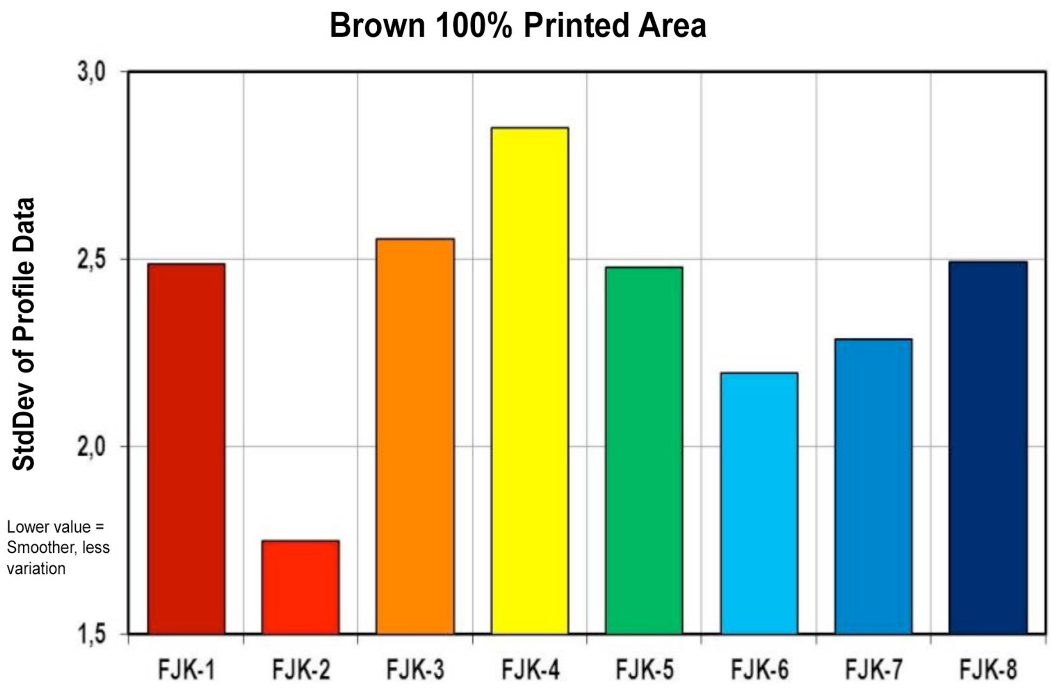
Graph 5: Colour difference between the inkjet printed tiles and the glaze.

SUPERFICIAL ASPECT OF THE SUBSTRATE

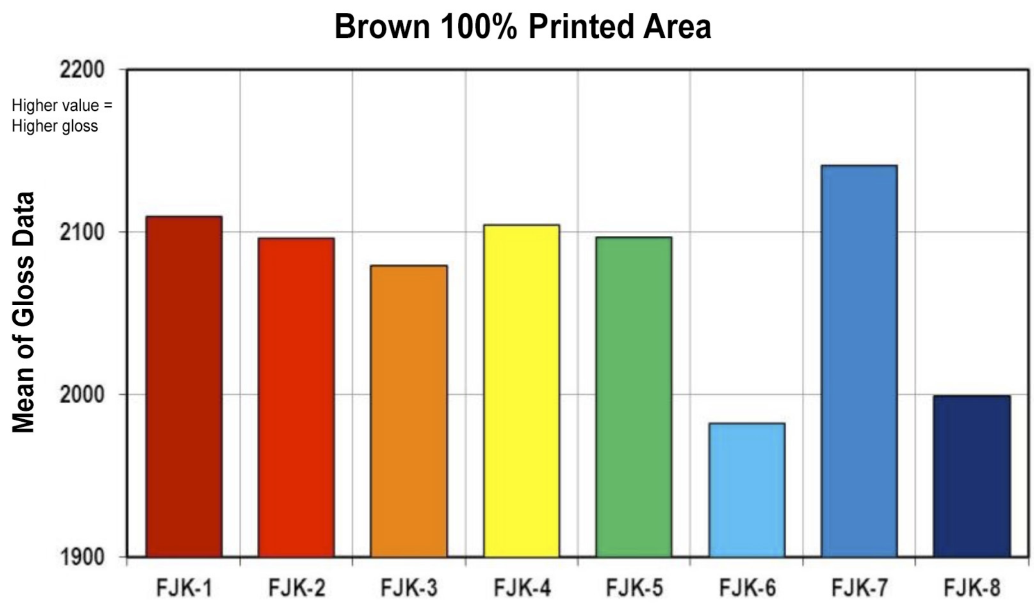
The surface roughness and gloss of the substrate were analysed with a laser profilometer.

The roughness was characterized by the standard deviation on the surface profile. The substrate made with the FJK2 sample presents a very low standard deviation. This kaolin is not generating any defect on the surface of the substrate (Graph 5).

The gloss values are low for the substrate made with kaolins FJK6 and FJK8. The other substrates present comparable gloss values (Graph 6).



Graph 6: Surface roughness of the different substrates.



Graph 7: Surface roughness of the different substrates.

7. CONCLUSIONS

The characteristics of the substrate for digital printing can be modified by the type of kaolin used in its formulation. The spread and absorption time of the inks are influenced by the surface characteristics of the substrate. The kaolin plays a significant role and particularly its particle size distribution. The particle shape is also key to providing a homogeneous surface to control the suction: the spread and absorption time. The stripping effect can be controlled by the choice of adequate kaolin.

After firing, kaolin can preferentially enhance one colour detrimental to the others. Some kaolins present a more neutral impact on the colour development.

The kaolin highly influences the surface finish of the substrate after firing. Only some kaolins present a low defect and glossy surface aspect.

A kaolin can combine both roles, bring the good suction and colour development required for the digital inkjet printing and giving a good surface finish after firing. The choice of the kaolin and its characteristics are key to optimizing the printing on the substrate.

REFERENCES

[1] Chris Nutbeem, Janet Preston, Anthony Hiorns& John Husband - The Influence of Kaolin Aspect Ratio on Offset Printability - TAPPI PaperCon - 2010.