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Effect of Temperature on the Ink Transfer of sublimation Printing Process

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ABSTRACT
The effect of temperature on the ink transfer of sublimation printing technology was investigated. The ink transfer was conducted by the colour density of single solid inks and the ink trapping of overprinted solid inks. The experimental results indicate that the amount of ink transferred from the colour ribbon to the substrate is determined by the thermal characterization of dye materials. The densities of single colour inks as well as the ink trapping coefficients obtain the highest values at the temperature corresponding to the endothermic peaks of the dye materials. This is the optimum operating processing temperature.

Keywords : Dye Sublimation, Temperature, Ink Transfer, Polymer Substrate

I. INTRODUCTION

Dye sublimation was selected as the ideal surface decoration technology for plastic parts [1]. In this technology, the dyes are transferred into the polymer substrate by means of sublimation, where the dye materials start in a solid phase and transform into a gas state when heat is applied [2]. The key parameter of the dye sublimation process is temperature. It is understood that this parameter directly affects the level of dye penetration into the substrate. However, the published research about this problem has very little. The literature identifies that the processing temperature can range from 138 - 300oC [3] presenting a wide range of operations. On the other hand, most researches focus on the level of dye penetration into the polymer substrate but do not describe how it influences the performance of ink on the substrates [1, 3]. Therefore, in this study, the effect of temperature on the ink transfer to polymer substrates in the sublimation printing process was studied.

II. EXPERIMENTAL

A. Materials

The polymeric material used to manufacture the printing substrate is Polyvinyl Chloride (PVC). The PVC cards have a size (CR80) 86mm x 54mm and a thickness of 760 mm.

In this work, a Nisca printer PR-C201 was used. This printer uses dye sublimation to print a high-resolution image in reverse directly onto the film base. The printer then transfers the image and film onto the card surface through heat and pressure, thermally bonding it to the card surface. The PR-C201 offers a high speed, 600 dpi, 24-bit colour. The dye sublimation inks are accommodated with the printer, YMCKO colour ribbon.

B. Printing process

A test target was designed to evaluate the ink transfer (Fig.1). This target consists of 4 solid ink patches C, M, Y, K, and 3 patches where solids are overprinted on top of each other, magenta on yellow, cyan on yellow, and cyan on magenta.

The printing process was set to the same parameters for all samples. The temperature was changed in the range from 120 to 200°C.

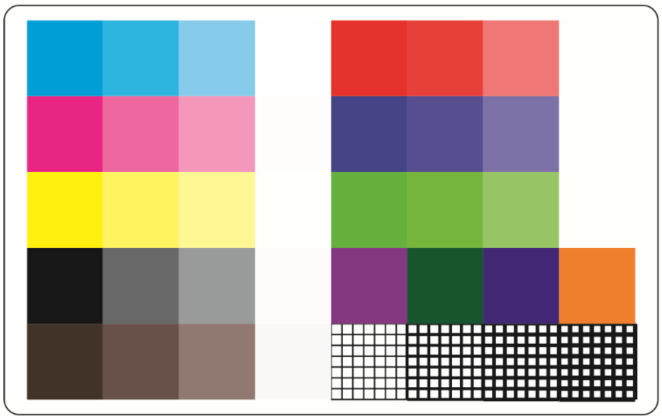


Figure 1: Test target

C. Ink transfer evaluation

Solid Ink Density – The ink film thickness is evaluated by the solid ink density that is measured at patches of solid ink. This method is based on the Lambert-Beer law, which states that the concentration of a solute is proportional to the absorbance. According to that, the thicker the ink layer, the stronger the absorption results in a higher colour density.

Ink trapping - Ink trapping is defined as the amount of the second ink transferred on top of the first ink during process colour printing. Ink trapping is a measure of how well the inks are "sticking" to each other. This factor is calculated as follows [4].

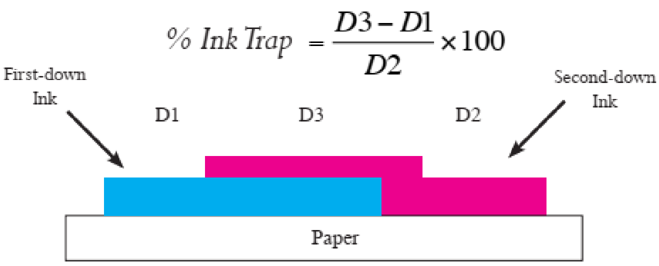


Figure 2: Density-based trapping fomular

Here, D1 is the solid tone density of the first-down ink; D2 is the solid tone density of the second down ink; and D3 is the density of the overprint solid.

The colour density values were measured by X-Rite DTP22 Color Digital Swatchbook Spectrophotometer.

III. RESULTS AND DISCUSSION

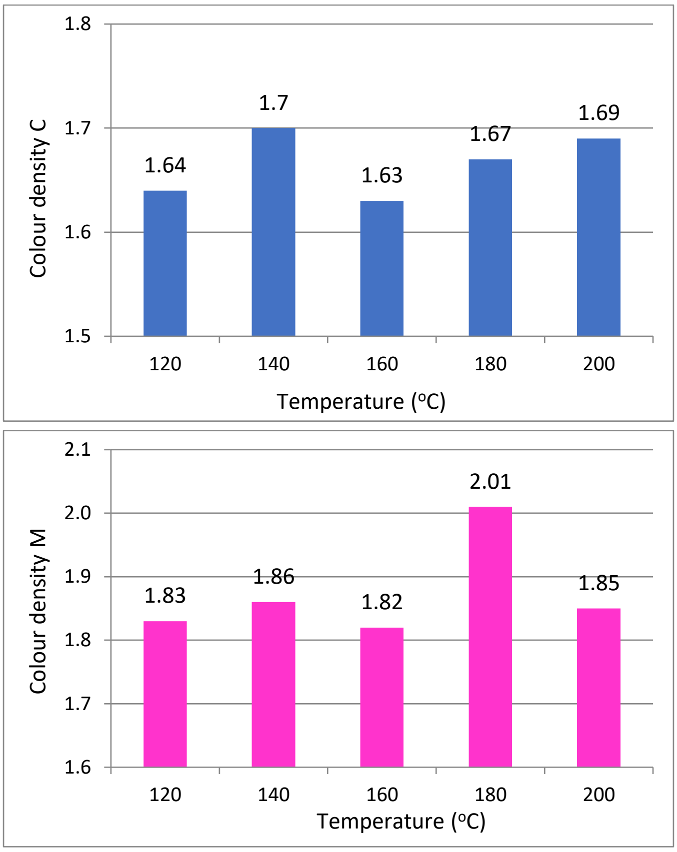
A. Effect of temperature on the ink transfer

In this study, the temperature was varied in the range of 120 – 200°C. All the samples were pressed at the same other conditions. The colour densities of solid patches C, M, Y, K are given in Table 1. The change of ink density as a function of temperature is presented in Fig. 3.

TABLE I. EFFECT OF TEMPERATURE ON COLOUR DENSITY OF SOLID INK

T°C	Colour density			
	C	M	Y	K
120	1.64	1.83	1.50	1.67
140	1.70	1.96	1.52	1.88
160	1.62	1.82	1.49	1.65
180	1.67	2.01	1.39	1.81
200	1.69	1.85	1.51	1.66

It can be seen that the effect of temperature on the ink transfer is rather complicated for all inks. From 120 to 140°C, the colour density increases with the temperature and gets the peak at 140°C. After this temperature, the color density tends to decrease to a limit of about 160 - 170oC and gradually increases again as the temperature is raised. This result shows that there is an endothermic peak at about 140°C, where the dye materials start absorbance thermal energy to sublimate and transfer from the ink ribbon to the substrate. Regarding the thermal characteristics of the standard dye materials, the Differential Scanning Calorimetry (DSC) experiments of Hohne et al. [5] indicate that the endothermic peaks are 119°C, 130°C, 142°C and 145°C for the C, Y, K and M dye, respectively. At these peaks, the dye materials start sublimation and cease at about 210°C. The ideal working temperature for these dye materials is 145°C [5]. Thus, the obtained experimental results are in good agreement with the thermal characterization of dye materials. It should be noted that in the ink transfer process of sublimation printing technology, the ink can penetrate very deeply into the structure of the substrate rather than on the surface. Therefore, the measured colour density values are not entirely proportional to the amount of ink transferred to the substrate. Published works [1, 3] show that the higher the temperature, the more ink penetrates the substrate. However, this process also reaches a limitation at a certain temperature depending on the structure and properties of the substrate material. With common polymer materials, this temperature is ranged from 180 to 200°C.



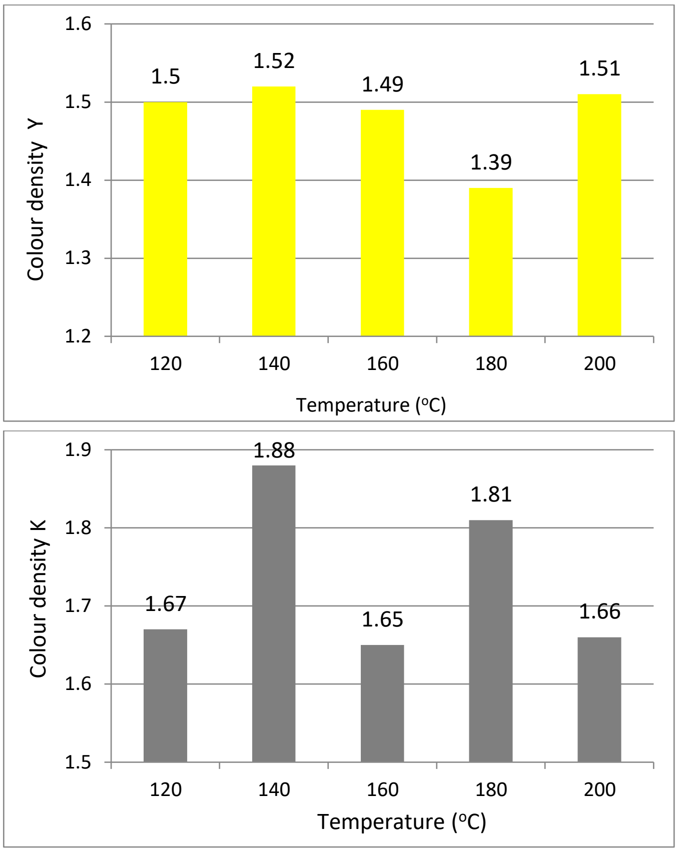
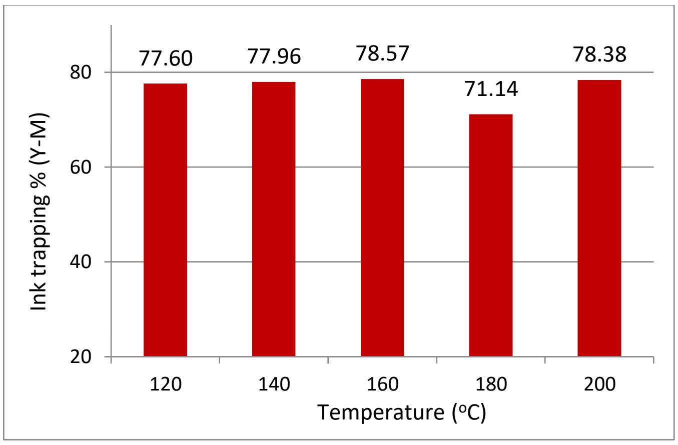


Figure 3 : Colour density of solid inks as a function of temperature

TABLE II. EFFECT OF TEMPERATURE ON INK TRAPPING

T°C	Ink trapping (%)		
	Y-M	M-C	Y-C
120	77.60	57.32	40.85
140	77.96	57.65	42.35
160	78.57	57.67	41.72
180	71.14	49.10	38.32
200	78.38	57.99	42.60



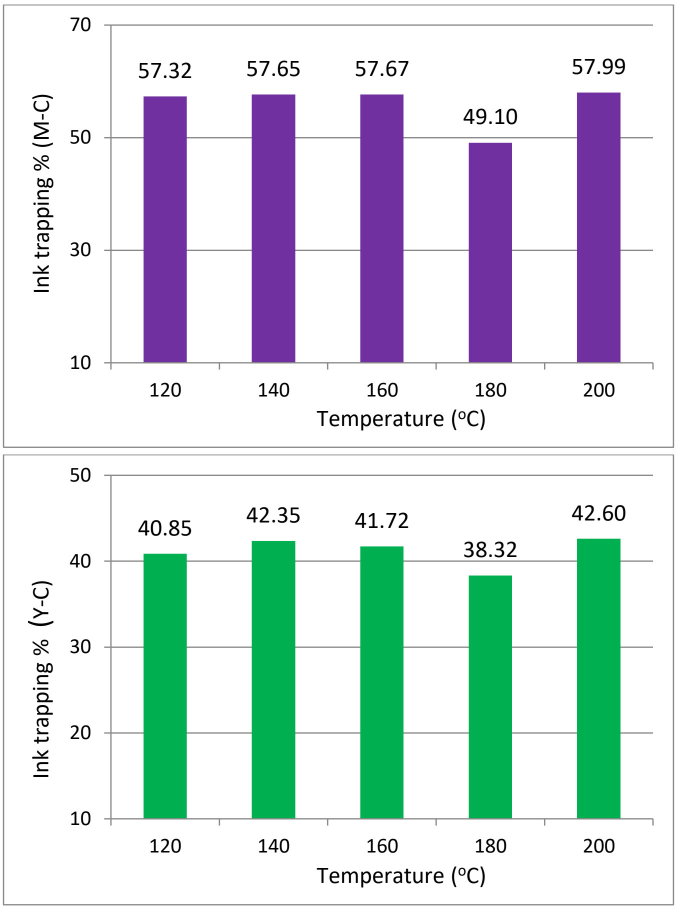


Figure 4 : Ink trapping as a function of temperature

Thus, under the effect of temperature, the ink amount of sublimation and penetration is not proportional. This explains the results in which colour density (determined by the ink layer on the surface) may decrease and then increase again with increasing temperature.

Experimental data show that the temperature does not have much influence on the ink trapping coefficient. At all investigated temperatures (except for 180°C), the ink transfer coefficient did not change significantly. Even so, the ink trapping obtains the highest value at 140ºC. The ink trapping coefficient M to Y reaches more than 78%. This is the optimal ink transfer coefficient not only with sublimation thermal printing technology but also with general printing technologies. With the process of transferring the ink C to Y and C to M, the efficiency is lower, about 57% and 42%. The results imply that the amount of C ink transferred to the previous ink is much lower than one transferred to the substrate. Therefore, the C ink should be the first down ink.

IV. CONCLUSION

The effect of temperature on the ink transfer of sublimation printing technology was investigated. The experimental results indicate that the ink transfer is determined by the thermal characterization of dye materials. The densities of single colour inks as well as the ink trapping obtain the highest values at the temperature corresponding to the endothermic peaks of the dye materials. The obtained results confirm this temperature is the optimum operating processing temperature.

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