CHAPTER IV

RESULTS AND DISCUSSION

In this thesis, water-based inkjet ink and water-based screen ink were evaluated on several ink properties. Two inks were prepared using the same pigment dispersion and two binders, which were both the acrylic family. These inks were printed on the cotton fabric. After printing, elucidation and comparison of print quality in terms of color, optical density, tone reproduction, air permeability and crockfastnesss were studied.

4.1 The Properties of Pigmented Inks

4.1.1 The Viscosity and Flow Behavior of Inkjet and Screen Ink

a. Inkjet Ink

Viscosity is the word most often used to convey an impression of the ease or degree of difficulty encountered when attempting to cause a material to flow and deformation. Conversely, viscosity is a precisely defined quantity, which relies on rigidly defined, measurable parameters. It still, however, is associated with the ability of a material to resist a deformation or flow. In order to appreciate the flow or rheological characteristics associated with a paint, one considers how a paint proceeds from manufacture to a final dry film. Generally, a paint contains four generic components:

polymers or resins, pigments, solvents, and a variety of additives. Each component has a dramatic effect on the rheology of the material at each stage of its life.[42]

Komasatitaya[43] deduced that S-711 binder, which has a hydrophilic property and good mechanical stability, could give a smooth ejection of the inkjet ink on all fabrics. Similtaneously, Sapchookul[44], concluded that the inkjet ink containing a 1: 2 pigment-to-binder ratio gave most of the best print qualities. Hence, S-711 binder and ration of pigment-to-binder of 1:2 were used in this research.

The ink formulation in this thesis was constant at a pigment-to-binder ratio of 1:2 by weight based on the total weight of the ink. The flow behavior and viscosity were determined at the temperature of 25 °C. Table 4-1 shows the viscosity of the cyan, magenta, yellow and black inkjet inks.

The inkjet ink is characterized as somewhat Newtonian fluid due to a relatively constant viscosity at various shear rates, which can be observed from the flow curve and viscosity in Figures 4-1 and 4-2, respectively. Figure 4-2 shows that curves were slightly decreased in apparent viscosity with increasing rates of shear that was the characteristies of shear thinning. The particle aggregation occurred in a colloidal system, then an increase in shear rate will tend to break down the aggregates, which will result, among other things, in reduction of amount of solvent immobilized by the particles, thus lowering the apparent viscosity of the system. The apparent viscosity of a system that thins on shearing is most susceptible to changes in the shear rate in the intermediate range where there is a balance between randomness and alignment and between aggregation and dispersion.[45] Nevertheless, the ink is still the Newtonian fluid, because their viscosity is converted a little. The inkjet ink should be the Newtonian fluid, which preserves a constant viscosity negligent of shear rate.

Table4-1 Ink viscosities of cyan, magenta, yellow, and black inkjet inks

Inks	Viscosity (mPa s)[a]
Cyan	5.06
Magenta	4.94
Yellow	6.25
Black	4.6

a = at 25 °C, spindle number 18 and shear rate at 250 rpm, Brookfield DVIII Rheometer

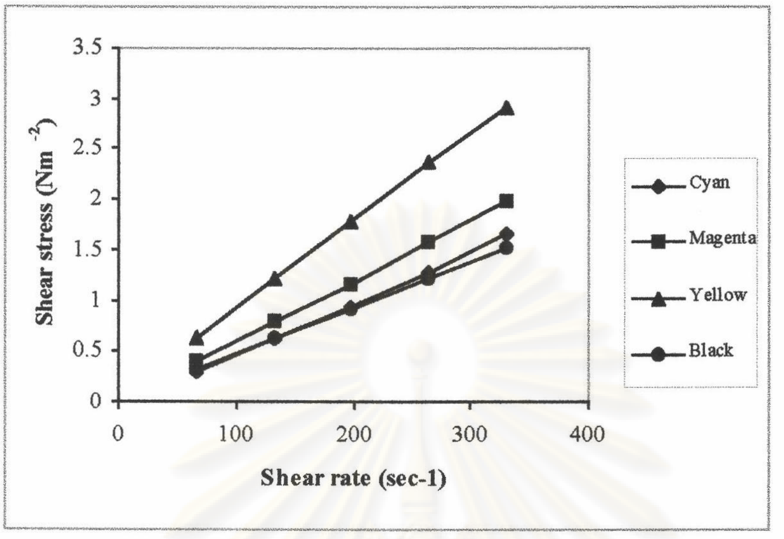


Figure 4-1 Flow characteristics of the inkjet ink at 25 °C

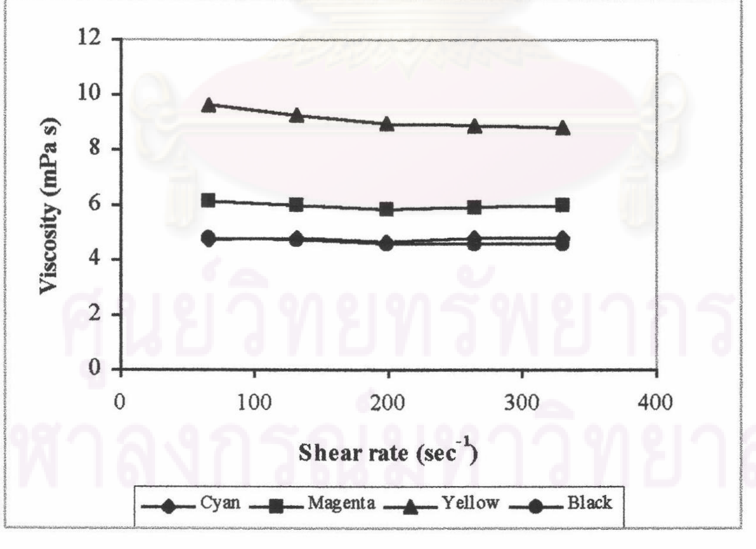


Figure 4-2 Dependence of viscosity of inkjet inks on shear rate at 25 °C

b. Screen ink

The fume silica was added in the preparation of screen inks. The increasing viscosity gives the non-linear viscosity behavior, since surface of fume silica is fully hydroxylated. When mixed with hydrophilic polymeric binder, a particle-molecule interaction occurred. This will lead to bonds creating a three-dimensional network structure, which is often called a "gel", as shown in Figure 4-3.[46] In comparison to the forces within particles or molecules, these bonds being often hydrogen or ionic bonds, are relatively weak: they rupture easily, when the dispersion is subjected to shear over an extended of time.[46]

Figures 4-4 to 4-5 represents decrements of viscosity of the screen ink when increasing shear rate that indicated characteristics of pseudoplastic behavior and have a yield value. The yield referring to a liquid system where a minimum shear stress must be exceeded before it starts flowing.[47] Besides the yield value depends on the presence of forces between the particles, either second valency forces or electrostatic forces. The phenomenon has been linked with the assumption of a degree of structure in the fluid,[48] in which fumes silica induces a particle-molecule interaction, thus initial curve represented high viscosity. Then, increment of shear rate will tend to break down of a three-dimensional network structure and of molecular orientation, which resultants drop in viscosity.

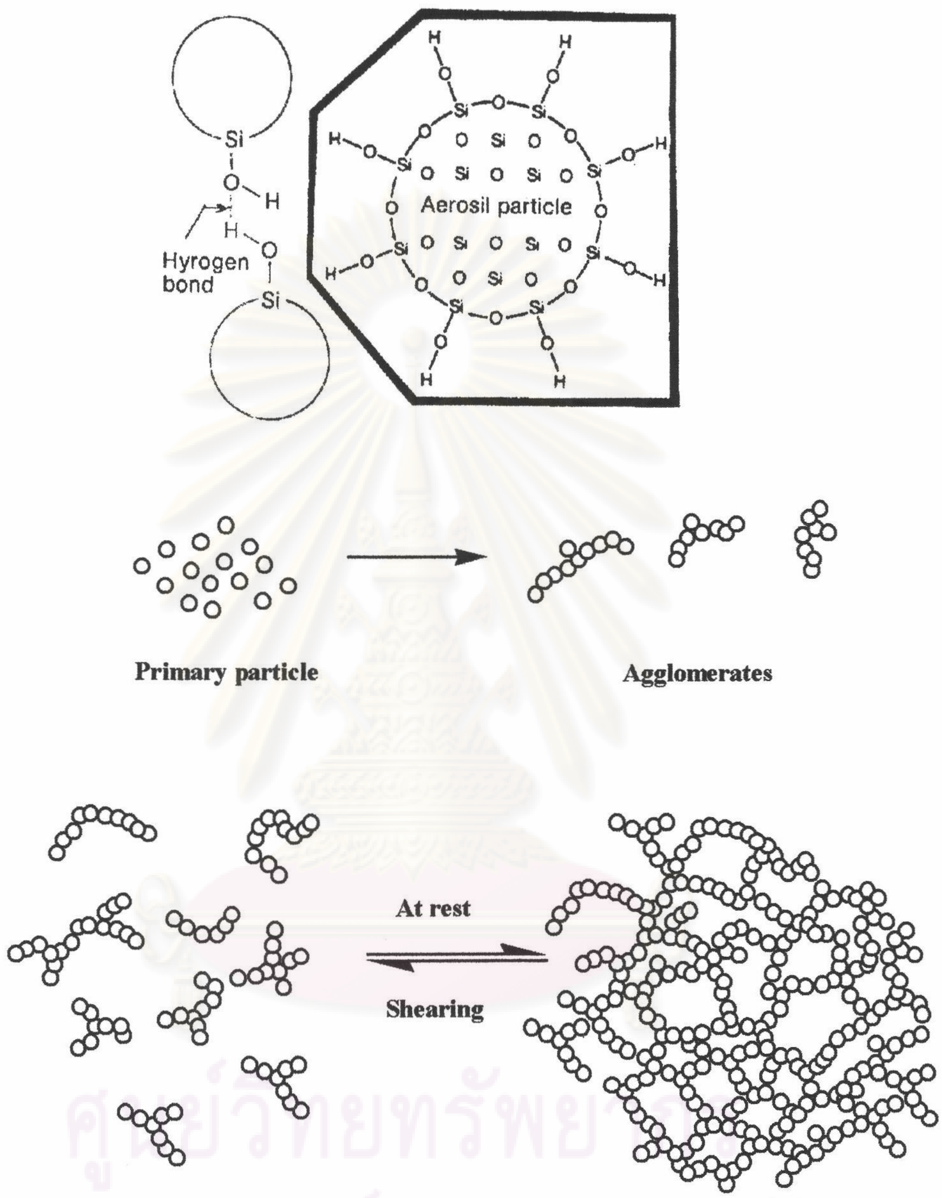


Figure 4-3 Particle-molecule interaction

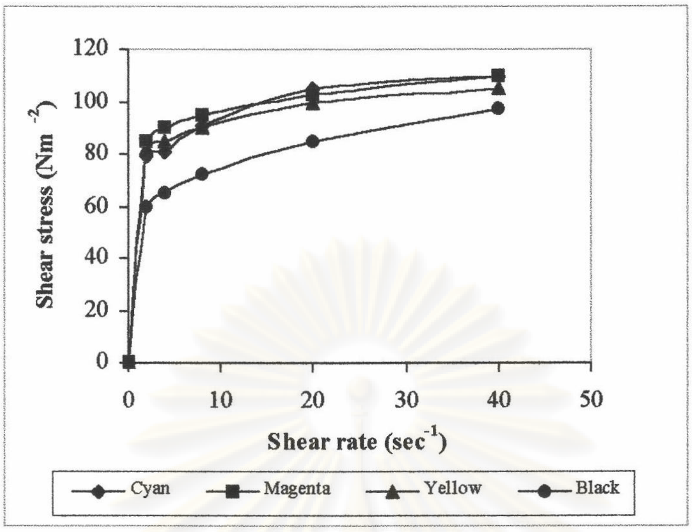


Figure 4-4 Flow characteristics of the screen ink at 25 °C

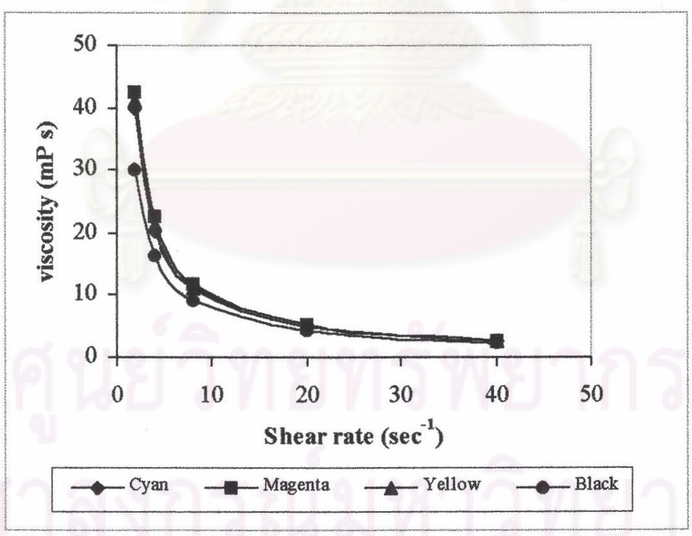
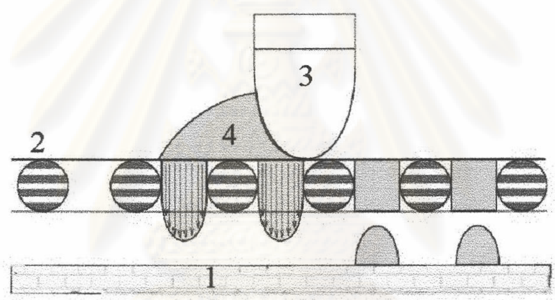


Figure 4-5 Dependence of viscosity of screen inks on shear rate at 25 °C

From the result of rheology of inkjet and screen inks, we found that the inkjet ink is water-like in consistency and characterized as Newtonian behavior. Screen ink is paste-like (short and buttery) and characterized as pseudoplastic behavior. Screen ink is applied by a scraper blade and is forced through the open meshes of the screen onto the substrate, as shown in Figure 4-6. The flow properties of the screen ink are critical since it is the aim to have sufficient flow-out to eliminate the screen raster, while at the same time the sharpness of the pattern must be preserved.



1 = substrate 2 = screen
3 = scraper blade 4 = printing ink

Figure 4-6 Cross section through a screen and a substrate during screen printing

Higginbotham[49] was first to analyze the relationship between printing behavior and .the effect of shear. The viscosity of a print past is usually changed by shearing forces, both under the doctor blade and as it enters the fabric. When the paste viscosity has been reduced and good contact with the fabric established, capillarity forces are probably dominant.

The ink must penetrate quickly into the substrate and not leave any of the colorant at its surface. In as much as rheology of both inks is very distinction, the penetration and wetting on the substrate is different and their impact to print quality too. Penetration of a liquid flowing under its own capillary pressure in a horizontal capillary can be described by Lucas-Washburn equation.[50]

$$\ell = (r\,\gamma\cos\theta\,/2\eta)^{1/2}\,t^{1/2} = K_A\,t^{1/2} \qquad (4.1)$$

where

ℓ = penetration distance after time, t

r = pore radius

γ = surface tension

θ = contact angle

η = liquid viscosity

K_A = absorption coefficient

From Equation (4.1), it found that penetration might be reduced or increased when increasing or reducing the liquid viscosity, respectively. Therefore, penetration was believed to be operative during printing, determining the sharpness or density of printed mark.

4.1.2 The Surface Tension of Inkjet Ink

Table 4-2 Surface tension of cyan, magenta, yellow and black inkjet inks

Inks	Surface Tension (mN m^{-1})
Cyan	40.8
Magenta	40.32
Yellow	41.28
Black	41.28

From Table 4-2, the surface tension of cyan, magenta, yellow and black inks were similar. Hence, the inks wet on the substrate similarly. Water provides the highest surface tension, which is 72 mN m^{-1}. This value is reduced to 40-60 mN m^{-1} by the other ink components, including colorants, polymers, and additives.[51]

4.1.3 The Stability of the Pigmented Inkjet Ink

Inkjet ink comprising pigments needs to be milled and filtered to much finer tolerances than for the conventional screen or the roller printing. Inkjet inks must be formulated with precise viscosity, consistent surface tension, specific electrical conductivity and temperature response characteristics, and long shelf life without settling or mould growth.[52] Chemical stability of an ink or dispersion is the assurance given that no agglomeration or particle size increase occurs. Physical stability refers to a system that has observable settling.[53]

As shown in Figure 4-7, at the initial stage of 1-3 weeks, little increase in viscosity was observed because particle aggregation might occur in the inks as shown in Figure 4-8. Consequently, the pigmented inkjet inks were corroborated to be steady, as measured every week that for two-month storage under room temperature at around 25 to 30°C. The steady state could be resulted from the non-interaction behavior or environmental stability. Because S-711binder is a non-ionic polymer dispersion, whereas the pigment dispersion is ionized. Any interaction between the binder and pigment dispersion in the ink system could not be possible to occur.

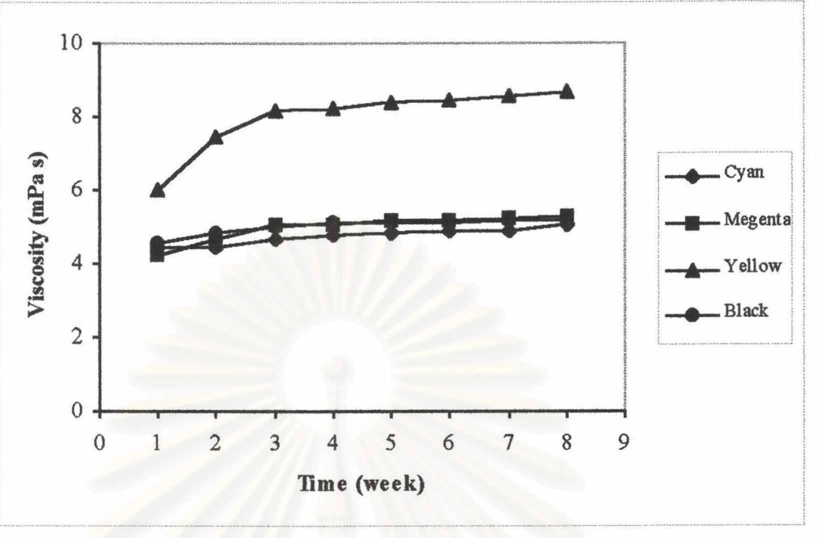


Figure 4-7 The viscosity stability of pigmented inkjet inks

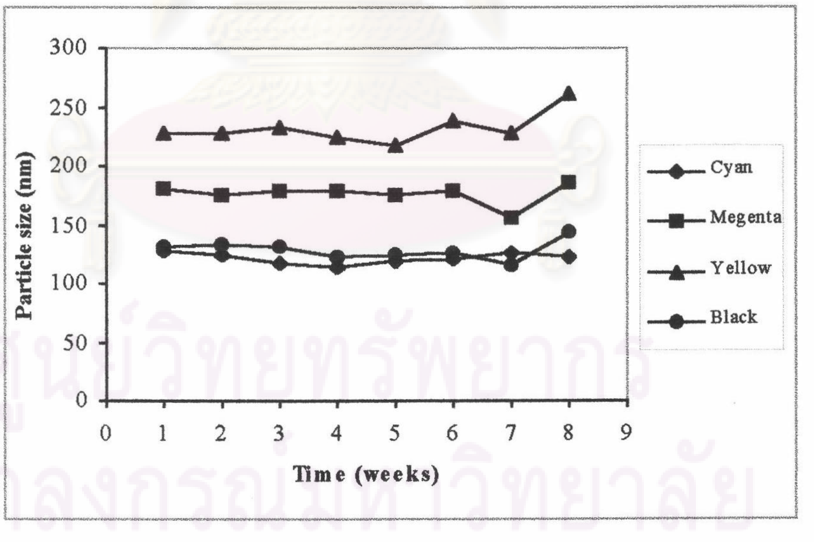


Figure 4-8 The particle size stability of the pigmented inkjet inks

Interpreting the results in Figure 4-9, it is evident that flow behavior of all pigmented inkjet inks is Newtonian in nature. This reveals that the ink maintains a constant viscosity regardless of shear rate. The flocculated state may be build up in ink at rest. Soft settled system could be easily reincorporated into solution by simple shaking or stirring. The pigment particles have been effectively dispersed by the dispersant so that there is no irreversible agglomeration or particle size increase.[53]

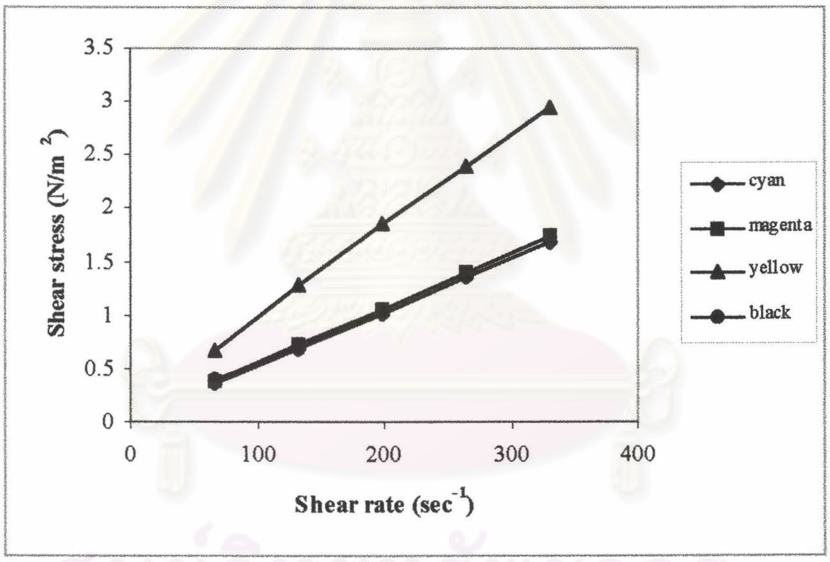


Figure 4-9 Flow characteristics of the viscosity after two-month storage

The initial particle size of pigment dispersion of cyan, magenta, yellow, black and S-711 binder in this study were 98, 177, 200, 132 and 161 nm, respectively. These particle sizes in a central range of 80-300 nm are a mean value, which is acceptable as most particle size of any materials in the ink. Hence, both fine pigment dispersion and binder have the same range of the particle size. Therefore, the ejections of C, M, Y, K inks with S-711 binder were very good, because there was no discontinuous streaks, as shown in Figure 4-10. The smooth and continuous lines indicate the best ink ejection and printability.

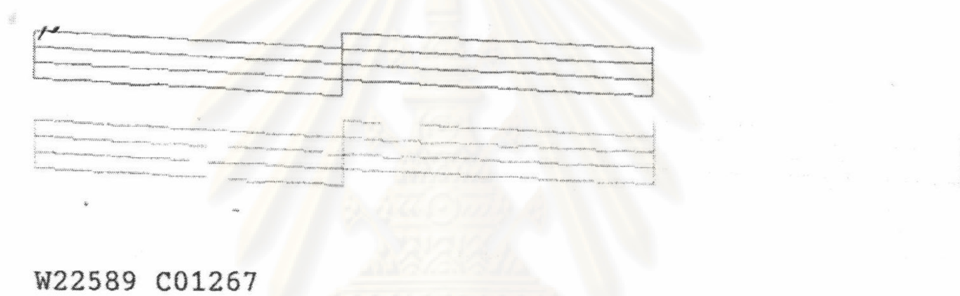


Figure 4-10 Nozzle checking of ejection on printing

4.2 The Print Quality of the Printed Cotton Fabric

Sapchookul et al.[44] concluded that the printed cotton fabric pretreated with poly(ethylene oxide) (PEO) yielded the better air permeability and stiffness. Thus, PEO was used in this experiment.

qualities. Figure 4-11 indicates that increasing printing time is an effective parameter on optical density (OD) value, and the optimum OD value was three-time printing on the same area, because four-time printing gave the same .OD value as three-time printing. This OD value is the normal OD for screen printing. Moreover, the best color gamut, color gamut volume, and color saturation are resulted from the three time printing of inkjet printing, as shown in Figure 4-12, Tables 4-3 and 4-4, respectively.

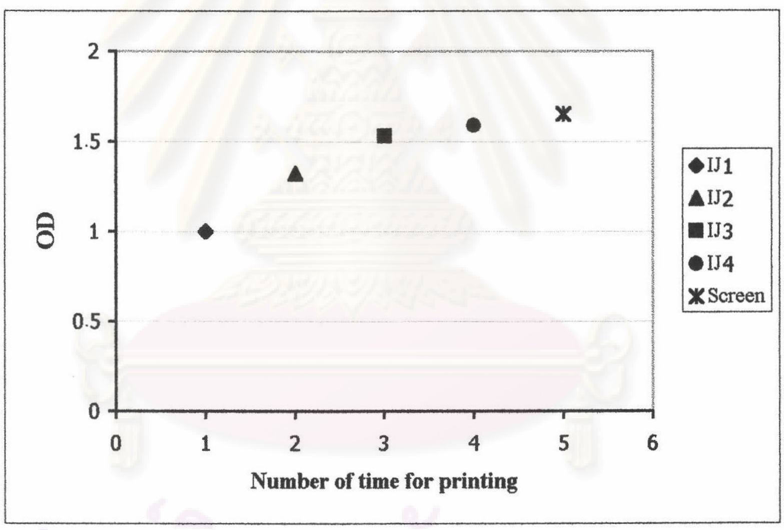


Figure 4-11 The relation between optical density (OD) and number of time for printing

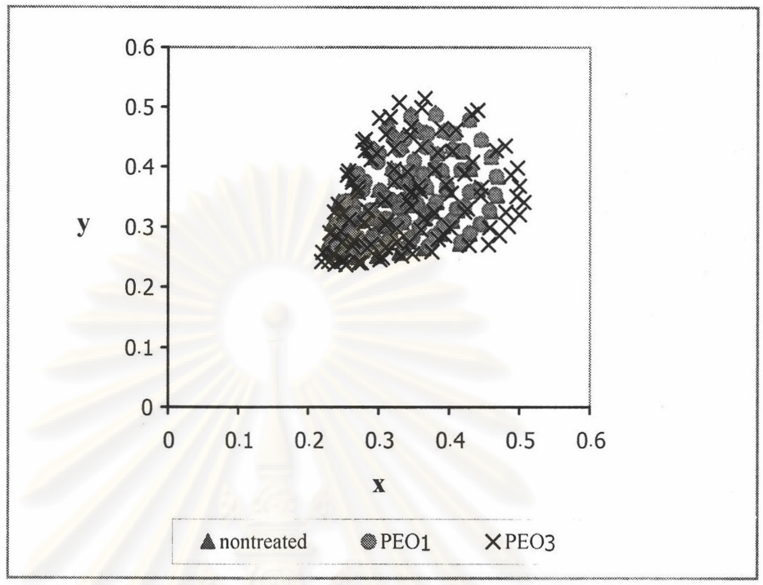


Figure 4-12 Color gamut in xy chromaticities coordinates of inkjet with the different time-printing on nontreated and treated cotton fabric (IJ1 = one-pass printing and IJ3 = triple-pass printing)

Table 4-3 Color gamut volume of iurnkjet ink and screen ink

Type	Color gamut volume
Inkjet	
• Nontreated (One-pass printing)	5193
• Treated	
- One-pass printing	5667
- Triple-pass printing	6330
Screen	
• Nontreated	5498

4.2.1 Color

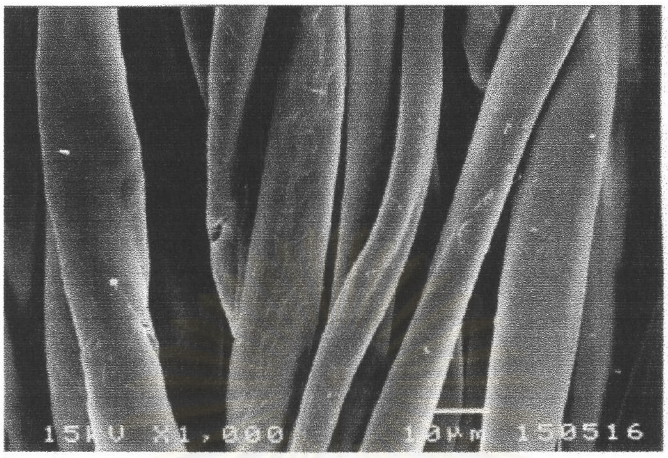
The measurement of color gamut, a standard color space, in Figure 3-1 is used to calculate the scope of color gamut from the experiments. The color gamut is usually presented in a CIE x-y chromaticity diagram. The color gamut imaginably should fix interiorly the color space. Besides, the data colors of the inkjet and screen inks were calculated for the saturation of color, S_{uv}. Table 4-4 shows the color saturation of inkjet and screen inks on the pretreated and nontreated cotton fabric, respectively.

Table 4-4 shows that the saturated print colors from inkjet ink were almost equivalence to those of screen ink. Two factors are responsible for this result. First, the pretreatment reagent had been applied onto the fabric to accept ink before the excessive spreading of the inkjet ink was taken place.[54] The SEM photographs in Figure 4-13, show that the pretreatment reagent was deposited on the surface of fabric. An importantly secondary factor was the repeat printing of three times that increased the amount of inkjet ink on the fabrics. The overlay gave the similar OD equalence to the ink printed by screen printing.

Table 4-4 The color saturation of inkjet ink and screen ink

Type	S_{uv}					
	C	**M**	**Y**	**R**	**G**	**B**
Inkjet						
• Nontreated (One-pass printing)	4.15	5.02	5.51	5.39	5.78	4.12
• Treated						
- One-pass printing	4.17	5.17	6.32	5.78	5.81	4.17
- Two-pass printing	4.27	5.20	6.34	5.88	5.82	4.26
- Triple-pass printing	4.98	5.40	6.43	5.91	5.83	4.39
Screen						
• Nontreated	3.66	6.03	6.51	6.21	4.92	3.65

The cotton fabric surface rendered less porosity by applying the pretreatment reagent, which blocks the inter-fiber void and could interrupt the absorption of the fluid inks. Accordingly, the pigments were hoarded on the layer of pretreatment agent when the ink gradually penetrated into the fabric. The amount of inkjet ink was increased by repeated printing, but it did not gave the color saturation value more than those of the screen ink, resulting in a high ink penetration. The penetration causes hue shift, smaller color gamut and saturation reduction,[55] but the color gamut did not decrease as shown in Figure 4-12 and Table 4-3, due to efficient pretreatment reagent. The ink penetration relates with the rheologic properties, as shown in Equation (4.1). However, the absorption and the reflectance properties of the ink films may affect hue and chroma.



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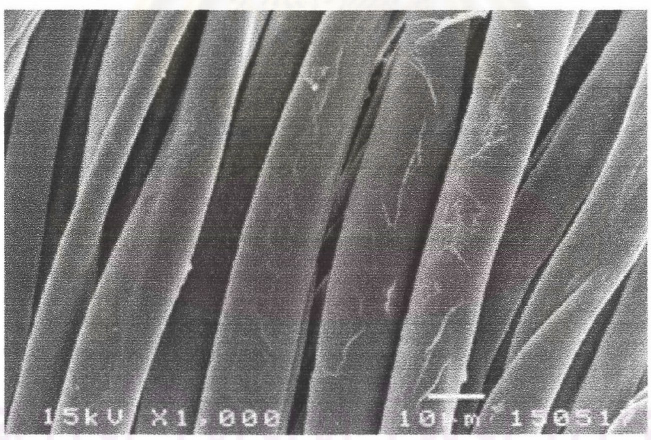
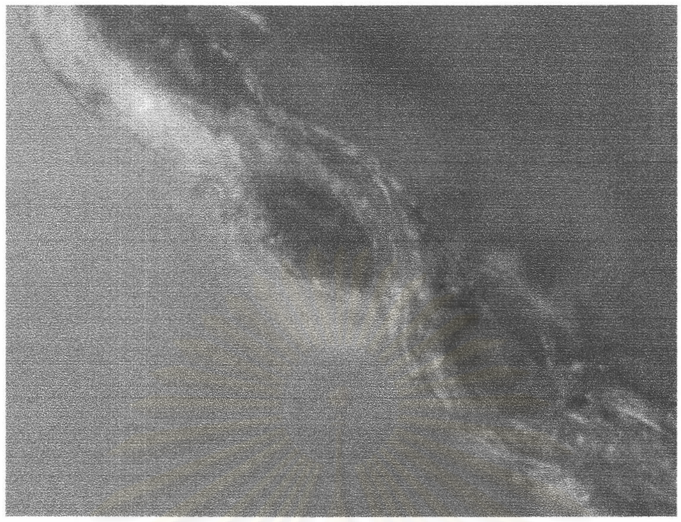
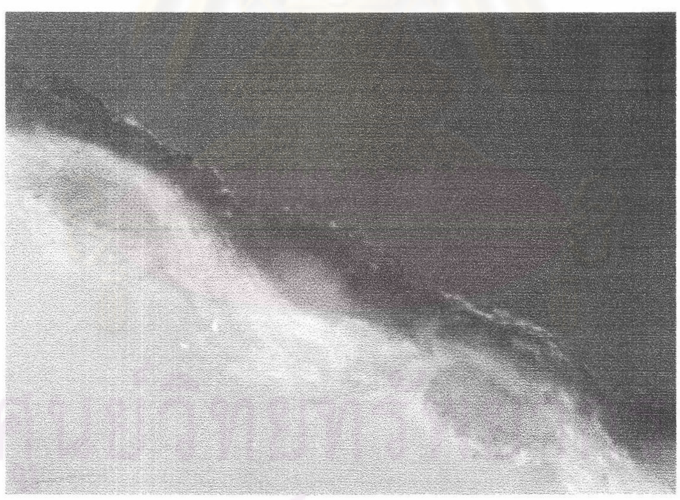


(b)

Figure 4-13 The SEM photographs of the nontreated and pretreated cotton fabrics (x 1000): (a) nontreated cotton fabric, (b) pretreated cotton fabric



(a)



(b)

Figure 4-14 The photomicrographs showing the depth of ink penetration of inkjet and screen inks (x 10): (a) cross-section of printed cotton fabric by inkjet ink (b) cross-section of printed cotton fabric by screen ink

From Equation (4.1), if liquid viscosity η is low a gave high penetration depth of ink should be observed than those of screen ink, as shown in Figure 4-14. This is, the depth of the ink penetration could be taken the amount of the ink situated on the surface of the fabric. Since, the amount of pigment of inkjet ink on the fabric surface was lower than that amount of pigment of the screen ink on the fabric. The pigmented inkjet ink on the fabric surface could reveal spectral reflectance of the specimens of the ink and also the fabric. While the screen ink received less impact of spectral power reflectance of the fabric, consequently, the color saturation of the inkjet was lower than that of the screen ink.

The spectral reflectance of a specimen impinge on the CIE XYZ tristimulus value, because CIE XYZ tristimulus value can be computed according to their definitions, provided that the the spectral reflectance of specimen, R(λ), is known. For example, X can be expressed as

$$X = K\int S(\lambda),\bar{x}(\lambda), R(\lambda) \tag{4.2}$$

The CIE XYZ tristimulus, X, Y and Z, can be further transformed into xyz chromaticity coordinated values.

$$x=\frac{X}{X+Y+Z} \tag{4.3}$$

$$y=\frac{Y}{X+Y+Z} \tag{4.4}$$

$$z=\frac{Z}{X+Y+Z}=1-x-y \tag{4.5}$$

Furthermore, the color gamut of screen ink was wider than that of the inkjet ink, but the green boundary of screen ink was narrower than the inkjet ink, as shown in Figure 4-15. Figures 4-16 and 4-17 represented the same color result with Figure 4-15. However, the color gamut volume of screen ink had a lower value than the inkjet ink, as shown in Table 4-3. The reason might be that the controlling of screen printing is mistake such as color registrations and ink formula that had fume silica additive. Fume silica, in a gel-like form, was dispersed in the screen ink, the ink flow was not smooth during printing. Very often, the screen ink may block the screen mesh. These problems influenced the color patch printing, and gave a poor color reproduction.

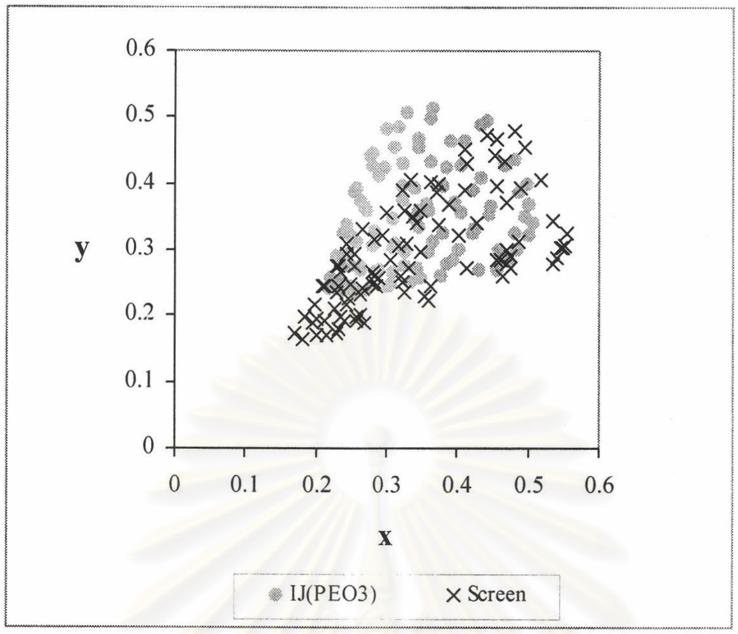


Figure 4-15 Color gamut in xy chromaticities coordinates of the inkjet and the screen inks

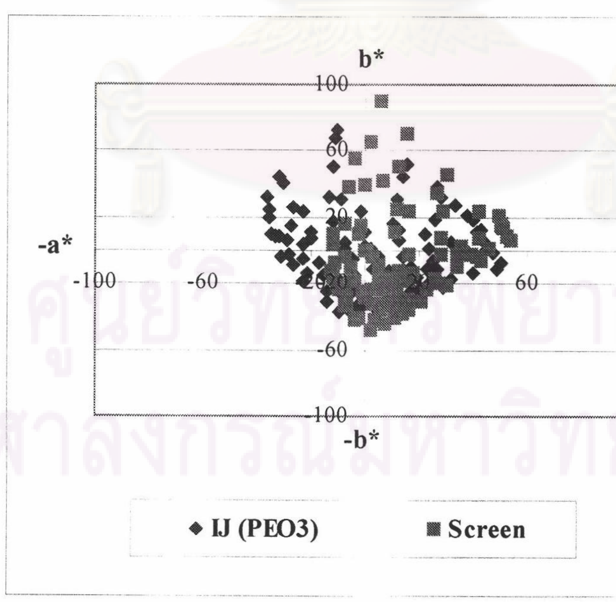


Figure 4-16 Color gamut in CIE a*b* coordinates of the inkjet and the screen inks

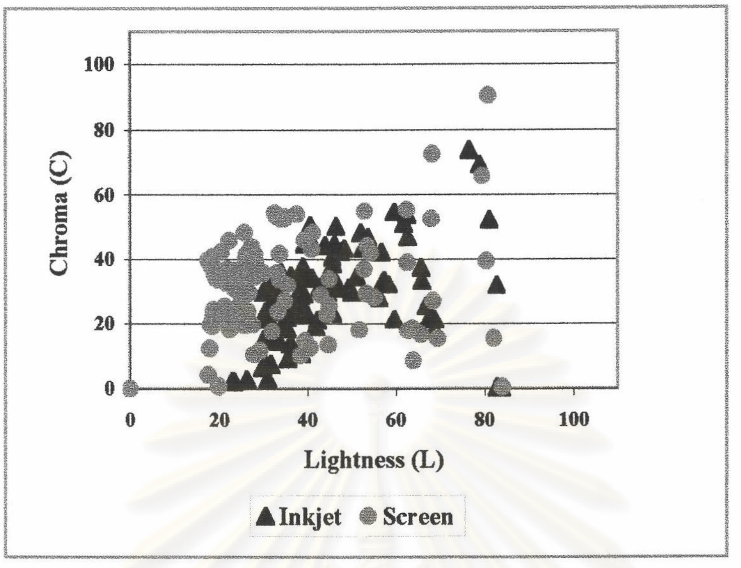


Figure 4-17 Relationship between chroma (C) and lightness (L)

4.2.2 Stiffness

The increment of bending length as shown in Figure 4-16 indicates the effect of treatment and direction of fiber structure on bending length effect. The stiffness is the ability of a material to resist deformation. The bending length value can indicate the stiffness of fabrics. The high bending length value means the higher stiffness of fabric. In the case of a yarn subjected to a tensile force or pull, stiffness is thus the ability to resist elongation.

It is more customary to express the flexural of the printed fabric in terms of stiffness by the following equation:

$$G = W \times c^3 \qquad (4\text{-}6)$$

where G = flexural rigidity, mg cm; W = fabric mass per unit area, mg cm^{-2}; c = bending length, cm. Table 4-5 shows the conversion result of bending length to stiffness. One can find that the higher the bending length, the greater the stiffness.

Table 4-5 The bending length and stiffness of printed cotton fabric by inkjet and screen ink

Color	Bending Length (cm)			Stiffness (mg cm)		
	IJ 1	IJ 3	Screen	IJ 1	IJ 3	Screen
C	2.52	3.08	3.15	220.52	407.59	507.28
M	2.55	3.10	3.18	223.35	410.52	532.21
Y	2.48	2.84	3.68	210.49	320.00	804.85
K	2.53	3.07	3.47	233.20	427.65	687.31

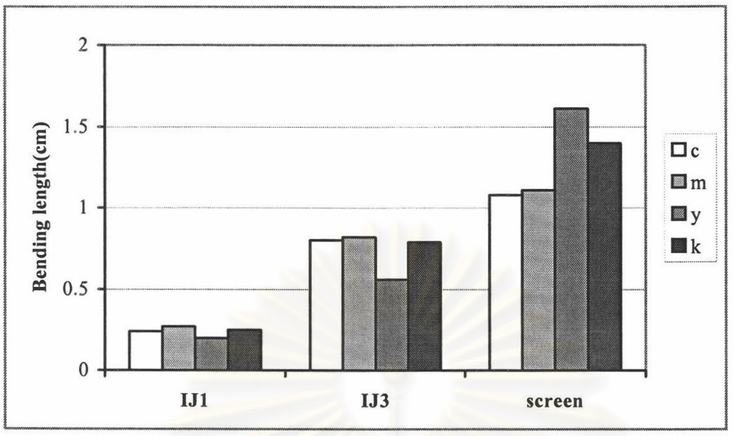


Figure 4-18 Effect of the pre-treatment reagent (PEO) on the bending length values at CD (Cross-machine direction) and MD (Machine direction)

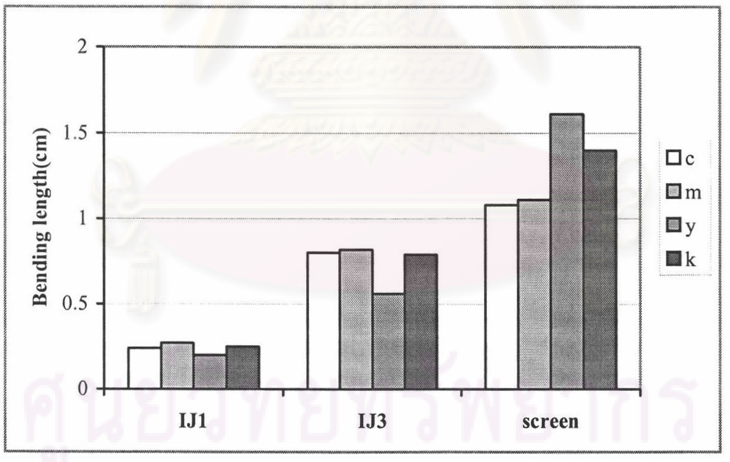


Figure 4-19 The increment of stiffness of the inkjet ink and the screen ink (IJ1=one-pass printing and IJ3= two-pass printing)

The pretreatment reagent (PEO) did not affect the stiffness value, hence, the bending length depends on the ink. Figure 4-19 indicates the increment of bending length

The pretreatment reagent (PEO) did not affect the stiffness value, hence, the bending length depends on the ink. Figure 4-19 indicates the increment of bending length on MD of the printed cotton fabric after printing with inkjet and screen inks. The stiffness value of printed cotton fabric with inkjet ink was lower the printed cotton fabric by screen ink.

It can be explained that three-time printing of inkjet gave the higher amount of inkjet ink on the cotton fabric, which was commensurated with the amount of screen ink. Furthermore, the higher amount of inkjet ink gave the high increment of bending length or gave more stiffness to the printed fabric because of the higher modulus of the binder in inkjet inks. Modulus is a fundamental measure of the stiffness of the material. As shown in Table 4-6, the BR-700 binder and S-711 binder gave a modulus range of between 700 ≥ E (MPa) ≥ 70, that are defined as semi-rigid with some elasticity.[56] These two films are similar in stiffness.

Table 4-6 Modulus, glass transition temperature (Tg) of the free film of two binders

Binder	Tg (°C)	Modulus (MPa) , 25 °C
BR-700	4.15	222
S-711	13.98	246

The glass transition temperatures, Tgs, of the BR-700 and S-711 binder were lower than the temperature of application, which gave the film behavior as elastic and viscous deformation. This indicates that these binders had similar properties, although the former is somewhat lower in glass transition temperature. Tg is affected by polymer structure. It is related, including intermolecular forces, chain stiffness and hardness. The inherent mobility of a single polymer is importance and molecular features, which either increase or reduce this mobility, will cause difference in the value of Tg. The high concentration of chain ends in a branched polymer increases the free volume and thus lowers the Tg, on the other hand, crosslinking lower free volume and raises the Tg, therefore, degree of crosslinking is increased, the material becomes hardness.[57]

4.2.3 Air permeability

Air permeability is the ability of air to pass through a fabric. Obviously, where openings between yarns or between fibers within yarn are large, a good deal of air will pass through the fabric. The ability of a fabric to resist air (low air permeability) or have air freely flowing through it (high air permeability) is dependent essentially on its thickness, porosity, configuration, geometry, type and amount of finish and coating.

Pigmented inkjet and screen inks were printed on the treated and nontreated cotton fabric, respectively. The pretreatment reagent did not affect air permeability because the aqueous polymer, PEO, the density of the deposits is not high enough but due to the nature of the fabric structure, the deposits contribute to the construction of the inter-fiber spaces as shown in Figure 4-13. Therefore, the fabric treated with the aqueous PEO polymer gave the better result of the air permeability. The air permeability depends on the characterization of ink that deposited on the cotton fabric.

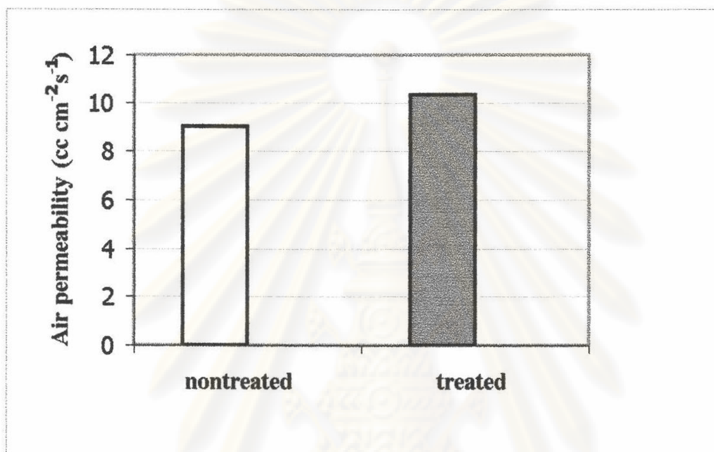


Figure 4-20 Effect of the pre-treatment reagent (PEO) on air permeability

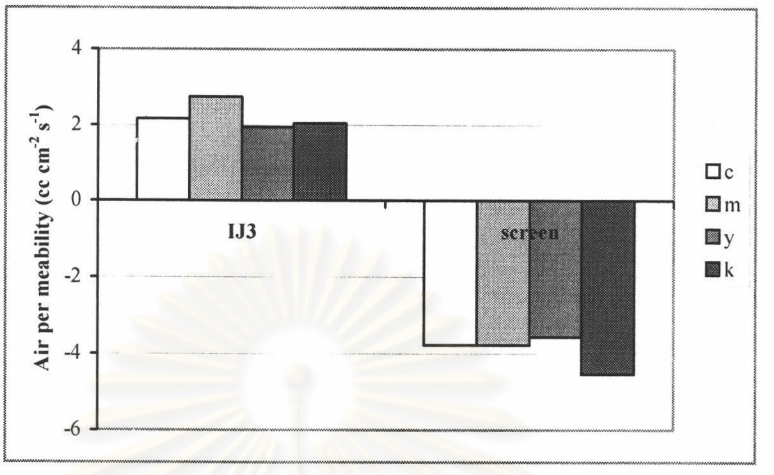
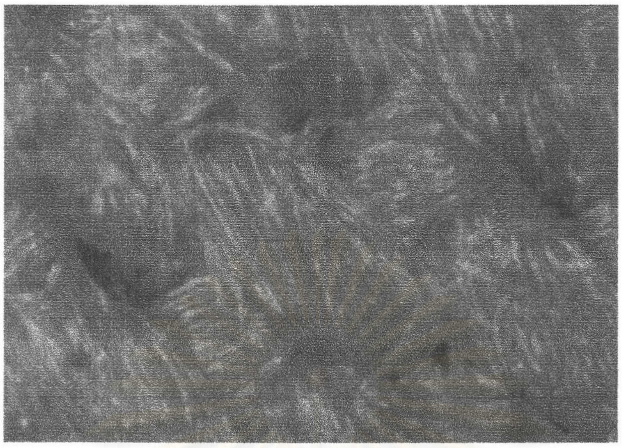
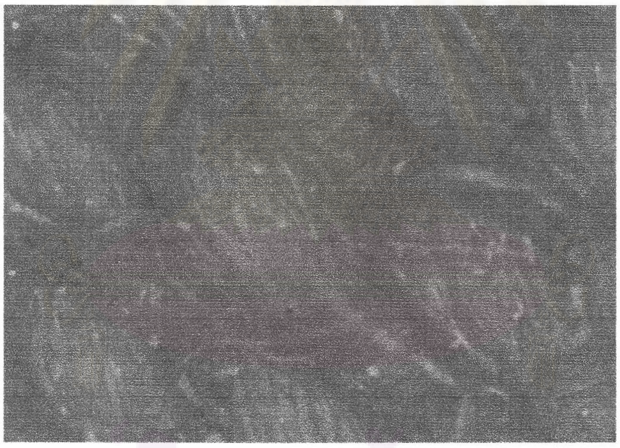


Figure 4-21 The change of air permeability of the inkjet ink and the screen ink

As shown in Figure 4-21, it is apparent that printed cotton fabric with inkjet ink increases somewhat the ability of air to pass through a printed fabric, whereas, the printed cotton fabric with screen ink decreases the air permeability. Some inkjet ink was penetrated into the fabric fibers and there was little ink localized on the top of cotton fabric surface (see Figure 4-22 (a)). The screen ink deposited on the cotton fabric formed a smoother ink film over the fabric surface, i.e. it also filled and covered the spaces between fibers, and blocked the inter-fiber spaces as shown Figure 4-22 (b). To conclude, the screen ink decreases the air permeability of the printed cotton fabric due to that the thicker ink layer covered over the surface of cotton fabric. The thick ink layer of deposits and encloses the fibers and filling the fiber interstices.



(a)



(b)

Figure 4-22 Photomicrographs of the surfaces of the printed cotton fabric ($\times 10$): (a) Inkjet ink, (b) Screen ink

4.2.4 Crockfastness

The printed fabric property of interest in the study was dry/wet crockfastness measured by a crockmeter, since some fabric lose color through crocking or rubbing against another fabric.

Table 4-7 shows the dry/wet crockfastness of inkjet and screen inks, which were printed on the treated and nontreated cotton fabric, respectively.

Table 4-7 Dry and wet crockfastness of the inkjet ink and screen ink

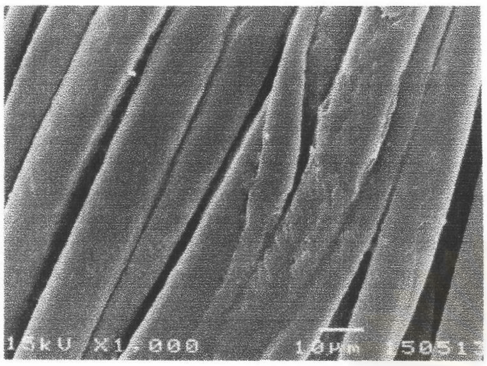
Inks	**Crockfastness on cotton fabric**							
	Dry				**Wet**			
	C	**M**	**Y**	**K**	**C**	**M**	**Y**	**K**
Inkjet ink	4	4	4	4-5	2	3-4	3-4	2-3
Screen Ink	1-2	1-2	1-2	1	1	1	1	1

5 stand = 100%, 4 = 80%, 3 = 50%, 2 = 25% and 1 = 5%

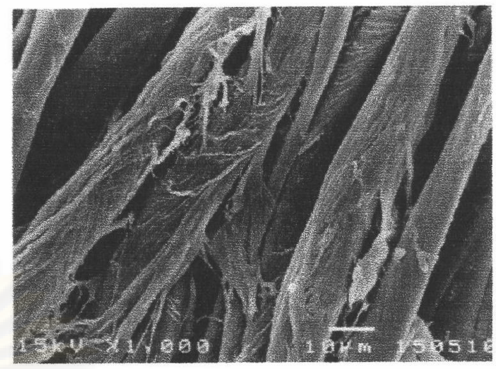
Table 4-7 shows that the dry/wet crockfastness of the printed cotton with screen ink was worse than the inkjet ink. The high crockfastness of the printed cotton with the inkjet ink was caused by the low ink pick-up on the surface of cotton fabric, as some inkjet ink penetrating into the fabric as shown in Figure 4-22.

However, the ink pick-up of the surface of the printed cotton with screen ink was higher because more ink was adhered on the surface of the printed cotton, as evidenced by a large solid phase of dry ink shown in Figure 4-22 (b). The high amount of the ink adhered on the surface of the fabric was an attribute of the lower level of crockfastness. Furthermore, when the ink film on the surface is rubbed, the ink film is peeled off. This behavior happens not only to the ink film, but also to the fiber, which was the determinate for threads, as shown in Figure 4-23.

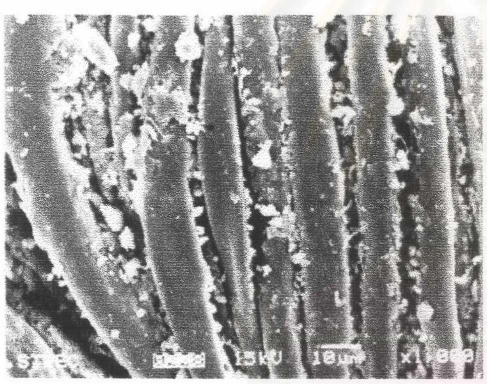
As shown in Figure 4-23, it was found that the damage of fiber is worsen in the wet crockfastness than the dry crockfastness. The wet film gives a lower Tg value because water is a plasticizer. The plasticizer improves the film flexibility due to an increase in the polymer's free volume, allowing more 'elbow room' for increased long-range segmental motion of the polymer molecules.[58] Besides, the modulus is lowered, thus the film strength decreased and the film flexibility could be increased. As per this reason, the ink film is not durable on rubbing.



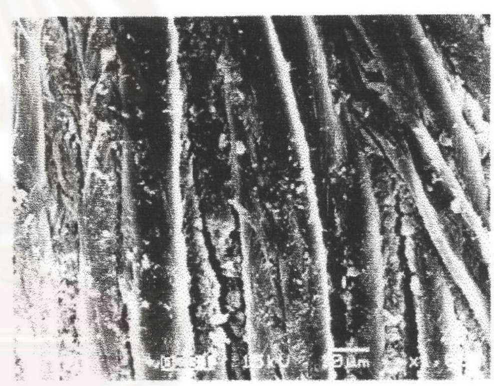
(a) Dry



(b) Wet



(c) Dry



(d) Wet

Figure 4-23 The SEM photographs of crockfastness test of the printed cotton fabrics with inkjet and screen inks: (a) dry crockfastness of the inkjet ink (b) wet crockfastness of the inkjet ink (c) dry crockfastness of the screen ink (b) wet crockfastness of the screen ink

4.2.5 Tone reproduction and density

Tone reproduction is the relationship between the level of gray (brightness) on the original and in the reproduction. Tone reproduction is probably the most crucial aspect since this affects whether a reproduction appears 'muddy' or 'dirty' or 'too bright'.

The required tone reproduction can best be expressed in terms that are easy to measure density. We can measure both the density of the original and the density of the prints resulting, and can, therefore, check the efficacy of the process.[59] Figure 4-24 shows the tone reproduction (a relationship between the density in the original and print) of inkjet and screen printing

Tone reproduction (Figure 4-24) of the both cotton fabric printed by inkjet and screen ink, are nearly similar. Densities of the print at 80 to 100 % original of the screen ink were higher than the density of the inkjet ink, since the inkjet ink has the lower ink viscosity than screen ink. As described eariler, the inkjet ink penetrates better into the fabric fiber, while the screen ink penetrates much less. This fluidity and penetration difference produce different ink film thickness on the fabric surface. Consequently, the more the ink holdout, the higher the ink density and saturation. The yellow color inkjet ink has a higher ink viscosity, thus the ink produces smaller sized droplets to give less ink on the fabric surface. The optical density of the yellow color inkjet ink is therefore lower.

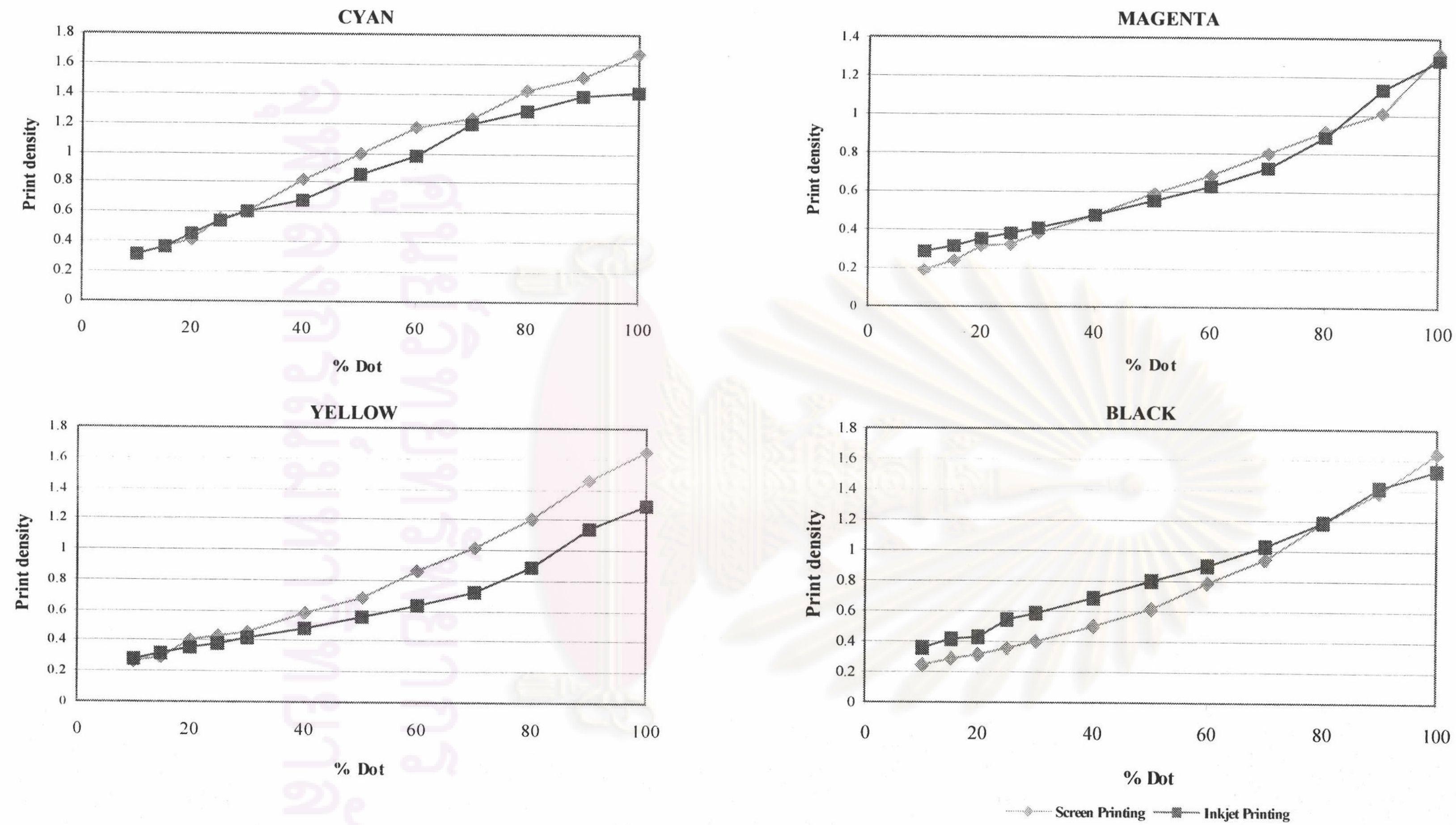


Figure 4-24 Tone reproduction of the inkjet ink and the screen ink

4.3 Comparison between Screen Printing and Inkjet Printing

To conclude, the comparison between the screen printing and the inkjet printing in terms of ink characteristic, processing sequence and properties evaluated were studied, as shown in Tables 4-8 To 4-10, respectively.

One should bear in mind the same pigment dispersion and two binders (BR-700 and S-711) of the acrylic family were used for the experiments. Two inks were composed of the pigment-to-binder (P:B) ratio of 1:2, the ink viscosity required for a good print quality for the two methods are dramatically different. Besides, if we compare the production time and cost involved in the two printing process, the inkjet printing needs less printing time and cost because it does not require the stencil making procedure, it is a closed ink printing, and less wash-up time, as shown in Table 4-9.

Finally, it is very interesting to note that the inkjet printing gives most of the desired properties. Hence, inkjet printing offers the possibility of substantial cost cuts in stencil makeup with a far-reaching elimination of collection risk. The efficiency of screen printing can be improved by using inkjet printing as a proofing system for time saving because a short yardage is used and the shorter makeready procedure before printing can be realized.

Table 4-8 Comparison of ink characteristic for screen and inkjet printings

Ink characteristic	Screen printing	Inkjet printing
Viscosity	high	low (water-like)
Binder	acrylic family	acrylic family
Pigment dispersion type	same	same
Pigment/Binder ratio	1:2	1:2
Pre-treatment	not used	used
Post-treatment	used	used

Table 4-9 Production sequences required for screen and inkjet printings on cotton fabric

Production stages	Screen printing	Inkjet printing
Pattern selection	needed	needed
Engraving data acquisition	needed	needed
Screen engraving	needed	not needed
Sampling	needed	needed
Printed textile	needed	needed

Table 4-10 Selection of printing process in relation to print quality of the treated, printed cotton fabric

Property evaluated	Printing process
number of passes	screen (one pass), inkjet (three passes)
color gamut	inkjet printing
stiffness	inkjet printing
air permeability	inkjet printing
crockfastness	inkjet printing
tone reproduction and density	inkjet printing and screen printing