Print Quality of Recycled Black Printing Ink Remixed from Wasted Process Color Inks in Offset Printing

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***Abstract*— The wastes from printing industry has variety types such as printing plate, printing substrates, printing ink, solvent, overprint varnish, chemicals, containers, and so on. Objective of this work was to recycle a black offset ink from wasted cyan (C), yellow (Y), magenta (M) and black (K) offset inks and testing quality. Experiment was, firstly, the wastes of black, cyan, yellow and magenta inks in offset presses were mixed and grinded in various proportions for preparing a recycled black ink. Secondly, quality of the remaking black offset ink was tested comparing to that of the standard black offset ink. Color and color different (ΔE) values of the recycled black offset inks was measured using a color spectrophotometer. Ink properties which were tack, viscosity, O/W emulsification, drying, setting time, UV fading, and rubbing resistance was tested. Printing quality such as print density, color value, and dot gain of the recycle black ink was evaluated. Results found that a mixing ratio of cyan, magenta, yellow, and black wasted inks, which had blackness close to that of the standard black offset ink, was 16.5%, 16.5, 17%, and 50%wt, respectively. The recycle black ink had a property of lightfastness poorer than that of the standard black offset ink.**

Keywords—printing; ink; offset; recycle; waste

I. INTRODUCTION

Wastes in printing industry include solid wastes which could consist of empty containers, printing plates, developed film, damaged products, etc., wastewater which may contain lubricating oils, waste ink, cleanup solvents, chemicals, and coatings, as well as metals such as silver, iron, chromium, copper, etc., air emissions of volatile organic compound (VOC) which is emitted from the use of cleaning solvents and inks, and alcohols used in lithographic printing.[1] Hazardous wastes sourced from printing industry is defined and regulated by governments. The management of municipal solid waste is one of the main costs encountered by local authorities in developing countries including Thailand. According to some estimates, these costs can account for up to 50% of city government budgets.[2] There were some research reported on recycling behavior, knowledge in waste separation, attitudes toward environment and global warming, situation of waste management in Thailand.[3,4] Cleaner waste management was described about a strategical requirement of a cleaner city with less negative impact on the environment.[5] The waste managed by recycling process is a prefer method of waste minimization with benefit on environment due to converting waste products into new products to prevent energy usage and consumption of fresh raw materials. This present work had an aim of turning ink-waste into non-waste. The main idea was waste minimization of the wasted printing inks in sheet-fed offset press by mixing wasted cyan, magenta, yellow, and black inks into a recycle black ink, which it was brought to used as a black ink in offset printing process.

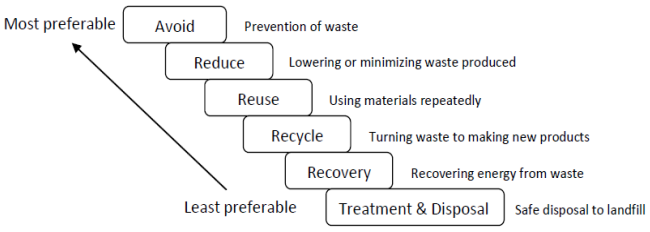

Fig. 1. *Waste hierarchy*

This was an aspect to minimize the ink-waste disposal as well as cost reduction of waste disposal in printing house.[6,7,8] There was a project study on a process of on-site ink recycling reported by U.S. Environmental Protection Agency which represented some evaluation on product quality, waste reduction, and economic issue.[9]

Printing ink is essential in printing process; it is daily used and wasted in a printing house. Its composition has environmental impact which is complicated such as pigment, resin, petroleum distillated solvent, and toxic heavy metals. Thus, the wasted printing ink needs to be collected and removed properly, for example in Aquatic effects, when used in accordance

with environmental regulatory requirements and industry guidelines, these compounds will not be released into the aquatic environment. We found that most of wasted-ink was left in ink-duct of each color-unit of printing press when printing process was done and after that it was removed out for disposal. These wasted inks were cyan (C), yellow (Y), magenta (M), and black (K) inks. According to the subtractive color mixing theory; C, M, and Y-ink mixing in equal proportion give neutral grey or black (Fig. 2).

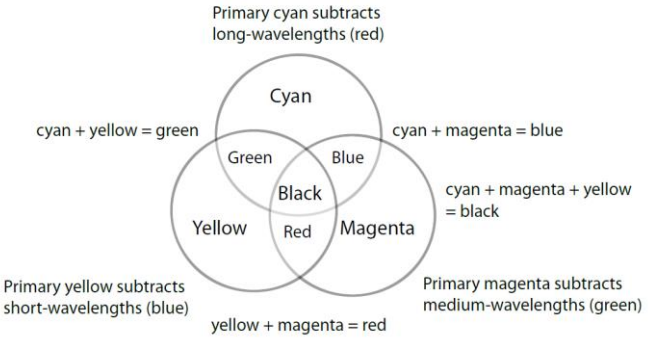

Fig. 2. *Subtractive color mixing*

However, the black-color (K) ink is necessary for printing process due to wrong-wavelength-absorption of cyan pigment, which is C.I. Pigment Blue 15, and magenta pigment, which is C.I. Pigment Red 122, failure absorption in a range of 400-500 nm wavelengths of magenta ink, and 400-600 nm wavelengths of cyan ink [10]. The wrong absorption of C and M pigments affect on poor color reproduction and low contrast to printed images, without giving neutral grey/black, but giving red-brown shade. Consequently, the black ink has important function in order to balance print-color reproduction.

Typical sheet-fed lithographic printing ink on paper substrate is drying oil-based type. Black inks of the highest density require the incorporation of specific wetting vehicles, generally based on low viscosity resins and alkyds to give high solids in the vehicle at moderate viscosity. The drying oil component of the offset lithographic printing ink is key of drying mechanism, which the drying oil reacted with oxygen in air to generate peroxide species and further polymerization to obtain dried inkfilm, whereas cobalt or manganese driers are catalyst in step of peroxide generation.[11,12,13]

It was explained that some waste ink can be recycled through an ink recycling service or in-shop. Blending colors usually requires some additives such as color toner to fine tune the color quality. Recycling allows blending several colors together into darker colors for reuse. The recycled ink compares favorably to new ink in tests for grind, residue, viscosity, tack, water content, and water pickup. On site recycling has been found to produce satisfactory final products. [14, 15, 16]

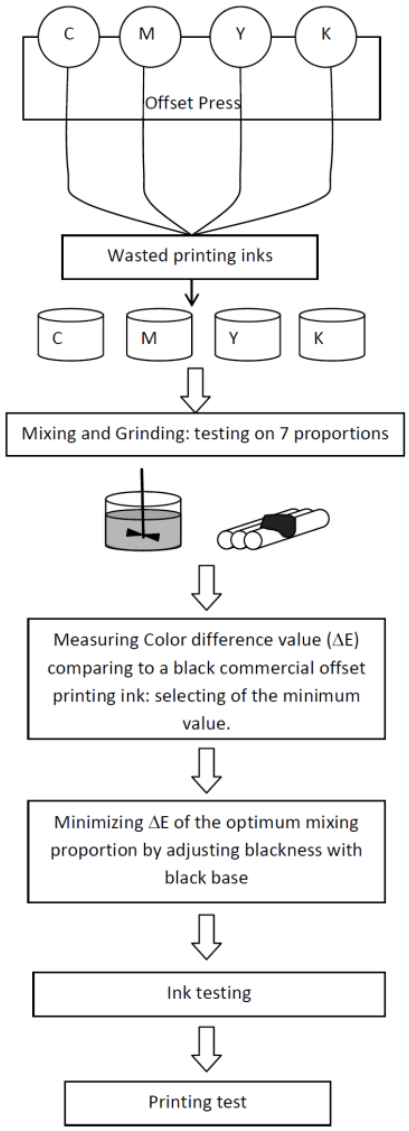

Fig. 3. *Flow diagram of recycle process*

II. EXPERIMENTAL

A. Materials

A set of process color inks: CMYK, which was sheet-fed offset lithographic printing ink (New Bestack PSO Process), and a black base paste received from Interink Co. Ltd. were used in the experiment. The black base paste was high concentrated black-pigmented oil based offset ink. a product of glossy coated offset paper having basis weight 85 gsm, was used as a printing substrate.

B. Procedure – Preparation of the recycled black offset ink

The waste CMYK inks from Ink-fountains in sheet-fed offset lithographic presses were collected for each color, separately, in an aluminum can or air-impermeable container to prevent auto-oxidation

reaction of drying oil in the ink. Fig. 3 shows flow diagram of ink-recycle process. At early stage, it was finding an optimum proportion (%wt) of wasted cyan, magenta, yellow, and black inks. The wasted CMYK mixing proportions tested were of formulas #1 to #7 as shown in Table I, using a mixing machine, Jungda mixer, model: SWFS-5.5. The mixed CMYK inks: #1-#7 were drawndown onto testing paper using RI printability testing machine, Akira, model: RI-2. Color values of CIELAB (L*,a*,b*) was measured using a spectrophotometer, X-Rite, model: 528. Color differences (ΔE) between those of 7 formulas of the recycle black in Table I and a standard black-offset ink were calculated follow as equation (1). The best CMYK formula would be a minimum color difference (ΔE) to the standard black.

TABLE I. MIXING PROPORTION

Wasted inks	Weight by total of the inks (%wt)						
	#1	#2	#3	#4	#5	#6	#7
Yellow (Y)	34	30	27	24	20	17	9
Magenta (M)	33	30	26.5	23	20	16.5	8
Cyan (C)	33	30	26.5	23	20	16.5	8
Black (K)	0	10	20	30	40	50	75

 # Stands for sample formula 1 to formula 7

$$\Delta E = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1/2} \quad (1)$$

Where; ΔE was color difference
ΔL* was L* of recycle black ink - L* of standard black ink
Δa* was a* of recycle black ink - a* of standard black ink
Δb* was b* of recycle black ink - b* of standard black ink

The next steps were adding black base paste into the best formula of the recycle black ink in order to improving blackness of the recycle black printing ink. The ink was drawdown onto testing paper. Color difference (ΔE) as equation (1) of a variety contents of 6, 8, 10%wt of black base was compared to the L*, a*, b* values of the standard black ink. Next, the recycle black ink, which was the best formula of waste-CMYK blended with the best black base content, was tested on some physical properties and print quality.

C. Procedure – Testing on Ink Properties

The physical properties of the inks were tested as following: fineness of grind using a grind-o-meter, viscosity and tack via a Laray viscometer, L-type, and Ink-o-meter (Toyo Seiki), ink and water emulsification tested via laboratory mixer (Kershaw). The recycle black ink was drawdown onto ink drawdown paper sheet using RI printability testing machine, Akira: RI-2. After drying completely, the drawdown samples was brought for testing setting time, drying time, rubbing, lightfastness, and gloss. The samples were tested in a controlled-temperature room approximately 25°C using RI tester (Akira), Printing ink drying time meter (Toyo Seiki No.460), rub tester (Pnshar, model: PN-PID), Fade-o-meter (Microsol Jame H., model: No.495), and digital gloss meter (Zehntner, model: ZGM 102), respectively.

D. Procedure – Testing on Print Quality

A recycle black offset ink which had the smallest color difference was brought to print via a sheet-fed offset press. On during offset printing, print density of solid area or 100% dot screen was controlled to maintain an optimum value with having highest print contrast to give the best print quality. The print contrast was a value that was calculated from print density of 80% and 100% dot screen onto printing sheets printed with CMYK standard offset inks as following equation (2) and the calculated values were shown in Table II.

$$\%\ Print\ contrast = \frac{SD-D80}{SD} \times 100 \quad (2)$$

Where SD *or* solid density was print density of 100% dot screen

D80 was print density of 80% dot screen

After printing step, the print sheets were brought to measure print density (solid density), L*a*b* color values, and %dot gain (equation 3) [17] using a color spectrophotometer, X-Rite: 528.

$$\%\ \text{dot gain} = \Delta\ \%\text{dot area on print} - \text{to on plate} \quad (3)$$

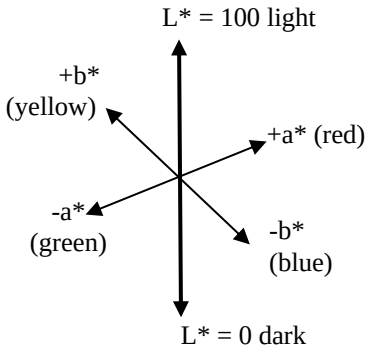

Fig. 4. *CIELAB color space*

TABLE II. PRINTING OF STANDARD CMYK INK

Print sheet	Black		Cyan		Magenta		Yellow	
	SD	CP (%)	SD	CP (%)	SD	CP (%)	SD	CP (%)
#1	2.01	20	2.12	26	1.99	28	1.31	10
#2	1.94	25	2.02	25	1.83	32	1.26	12
#3	1.85	24	1.93	28	1.75	35	1.22	13
#4	1.77	33	1.82	34	1.66	36	1.17	17
#5	1.67	33	1.74	36	1.59	36	1.12	21
#6	1.54	36	1.62	37	1.48	37	1.07	22
#7	1.42	37	1.53	38	1.38	37	1.04	23
#8	1.35	41	1.42	39	1.30	39	0.98	21
#9	1.24	40	1.35	38	1.22	38	0.88	18
#10	1.20	38	1.29	37	1.18	37	0.81	15

CP stands for print contrast
 # stands for one sampling-sheet selecting every 10 printed sheets

III. RESULTS AND DISCUSSION

Formula #6: Y17%, M16.5%, C 16.5%, and K50% by wt, was found that this proportion had the least color difference to the standard black, comparatively. To minimize ΔE, the black ink mixing in the formula had the most effect on the blackness of the recycle black. Adding of the waste black ink should not be over than 50% wt which could gain the color value close to the standard black (see Table II and III). The color inks (C, M, Y) had less influence to blackness of the recycle black with little change on the values of a* and b*. Considering on value of a*, red was higher than that of the standard because of the wrong wavelength absorption of the magenta ink, it might suggest to increase amount of the cyan ink. In addition, the mixing of cyan, magenta, and yellow inks effected to darken the black (Blackness of the standard black ink was from black pigment, the black ink had not any of cyan, magenta and yellow pigments).

TABLE III. COLOR VALUES AND COLOR DIFFERENCE

CIE Lab	Stan-dard black	Recycled black (Formulas, #)						
		#1	#2	#3	#4	#5	#6	#7
L*	16.86	27.08	23.13	21.69	19.93	18.22	16.12	12.06
a*	0.78	-0.48	1.50	1.65	1.89	1.85	1.84	1.22
b*	0.81	-0.39	-3.18	-1.78	-0.50	-0.34	-0.77	-0.30
ΔE	-	11.08	7.11	5.29	3.33	1.81	1.61	4.85

TABLE IV. COLOR VALUES AND COLOR DIFFERENCE

CIE Lab	%wt of black base paste in formula #6		
	6%	8%	10%
L*	15.77	17.65	16.77
a*	1.80	1.00	1.71
b*	-0.63	0.51	0.17
ΔE standard K - recycle K	1.70	0.88	0.93

Table IV shows the result of additional mixing of the black base into ink formula #6, at 8% wt of the black base gave the minimum color difference between the recycle black and standard black, which adjusted blueness (b*= -0.77, Table 3) across to yellowness (b*=0.51,Table IV). The high redness from a*=1.84 of the formula #6 (Table 3) was also reduced to get value of 1.00 (Table IV). ΔE of the 8%wt had the lowest value, lesser than ΔE =1.00, which was the smallest color difference the human eye can percept. Print image of the recycle black ink possibly had reddish grey because a* value was higher than b* value; 1.00 and 0.51, respectively.

Fig. 5 shows the regression curves of the waste K, C, M, and Y ink amounts on L* value of the recycle black ink. Equations to estimate mixing amount of the waste CMYK inks were as equation (4)-(6)

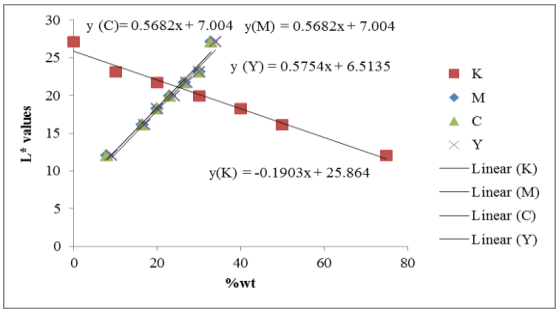

Fig. 5. *Regression of L* values dependent on amount of waste K, C, M, Y inks*

$$\%\text{wt of waste K ink} = \frac{L^* - 25.864}{0.1903D} \quad (4)$$

$$\%\text{wt of waste C or M inks} = \frac{L^* - 7.004}{0.19030.5682D} \quad (5)$$

$$\%\text{wt of waste Y inks} = \frac{L^* - 6.5135}{-0.57542D} \quad (6)$$

Since target value of the L* value was 16.86 of the standard black (see Table III), therefore the waste black ink calculably was 47.32%, the waste C, M was 17.35%, and the waste Y was 17.98% when calculated from equation (4)-(6).

TABLE V. PROPERTIES OF THE INKS

Properties	Standard black ink	Recycle black ink
Fineness of grind (μm)	5	7.5
Tack (g·m)	9.4	8.0
Viscosity (Pa·s)	290.83	315.3
Setting time (min)	12	13
Drying time (hr)	6	7
O/W emulsification (%)	46.0	44.0
Gloss	74.0	74.0
Rating scale of rub test	3.5	3
Lightfastness (hour)	80	20
Transparency	117.65	127.72

TABLE VI. COLOR VALUES ON OFFSET PRINT

Quality	Printed sheet of standard black ink	Printed sheet of recycle black ink
print density (Black)[a]	1.36	1.29
L*	22.56	26.96
a*	-0.06	1.00
b*	0.06	0.29

[a] *at Solid density of C was 1.45-1.47, D of M was 1.28-1.29, and D of Y was 1.02-1.03*

Property of the ink formula #6 : Y17%, M16.5%, C 16.5% and K50% by wt with adjust blackness at 8 %wt of the black base had the properties as showed in Table V. These properties were commonly tested when making an offset ink in an ink manufacturing. Consequently, the ink properties of the test recycle black and the standard black offset inks were measured and compared. Since the fineness of the recycle black ink was not as low as 5 micrometer, it might probably effect on some ink properties such as rub fastness. O/W emulsification, tack, setting time was little difference. Gloss was good, which was the same gloss value between the recycle and the standard inks. The much difference was light fastness on fading because the standard black ink was composed of black pigment. Not only that the recycle black ink had the black pigment, but also the ink had the C, M, Y color pigments. Yellow pigments had comparatively lowest light fastness than that of the cyan, magenta, and black pigments.[18] Due to high fading of yellow pigment component, the content of the waste yellow ink in mixing component should be reduced lower than 17%wt to enhance lightfastness.

In print quality test at the same printing condition and ink feeding, the printed sheets showed that the solid density of the recycle black ink had lower than that of the standard black ink with lighter L* value (26.96). Little higher a* value as showed in Table VI was evident that the print image consequently had little reddish image. Fig. 6 was result of dot gain on the tested print, it showed that dot gain of the recycle black ink was similar to the standard black ink as seen from midtone to shadow area. The recycle black ink had little higher dot gain than that of the standard black ink resulted in little darker on the print image. The poor dot gain on the printed sheet of the recycle ink was reflected the lost viscoelastic property of the recycle ink.

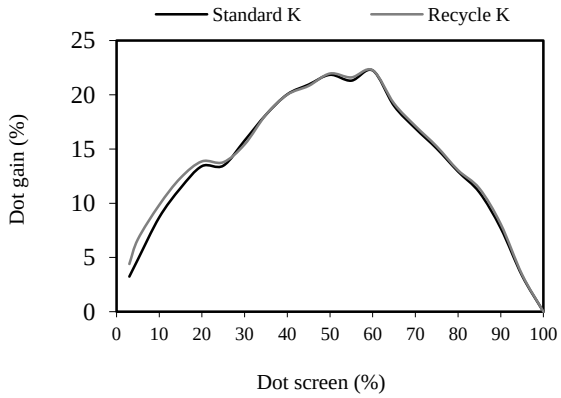

Fig. 6. *Dot gain of the print sheets of the recycle black ink (grey line) comparing to the standard black ink (black line)*

Fig. 7. *Print image of the standard black ink (Left), and the recycle black ink (Right)*

IV. CONCLUSION

The ink property of the rycylce black ink was totally similar to that of the standard black offset ink, except high lightfastness of the recycle ink, which might be improved by decreasing of the waste yellow content. The recycle black ink gave little difference of print production to the standard black ink with small lower print density and poorer dot gain. For reddish gray on the print image, the grayness probably improved with increasing % wt of the waste cyan ink. On the other hand, since the drying oil based ink had drying mechanism by oxidation polymerization, so a conventional offset ink composed of drying oil vehicle was typically sensitive to oxygen. Therefore, it was suggested that the conventional offset ink should be kept carefully in a container with avoiding ink surface contacting to the air to preventing unrecyclable ink due to ink drying and skinning in the container. Formulation of the recycle black offset ink had possibility for further development. It was agreed that the printing house can use this method to eliminate the wasted ink. It was also estimated that purchasing cost of a new black offset ink for printing process in the printing house was reduced for about 39%.

ACKNOWLEDGMENT

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