End Point Criteria for Evaluating Image Stability of Digital Prints

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Abstract

A new method for evaluating display life of digital printing materials is discussed. We propose a new criterion for estimating end points using “Modified Image Grade N’” which integrates monocolor fading, gray fading, stain and their balance. It shows the retention of total image quality .We can estimate end points using some threshold of “N’”. Xenon light exposure testing was performed on some digital printing materials such as AgX, D2T2, xerography, and inkjet color photographic prints. End points were calculated on each material with “N’” and other criteria such as ISO 10977. An end point with “N’” matches subjective evaluation better than other methods that define end points separately for color image, gray image, and stain.

Introduction

Non-AgX digital printing systems such as Inkjet, D2T2 have image quality comparable to conventional AgX systems. As they obtain better image quality, image stability of printing materials becomes more important. It is of value to estimate and compare their life. But the degradation behavior of non-AgX printing materials varies and in some cases is so far from that of AgX. Here we discuss an evaluation method to estimate display life of digital printing materials. We propose a new criterion for estimating the end point using “Modified Image Grade N’”, effectively applicable to non-AgX printing materials. Suitability is examined by subjective evaluation of printing samples from xenon light exposure testing.

Criteria for Life Estimation

Here we explain three already existing methods that give some criteria for end points used for life estimation. Later, we introduce our new one, “Modified Image Grade N’”.

ISO 10977 and Wilhelm Method

ISO 10977 and Wilhelm method define end points separately for color image, gray image, and stain.[1,2] End points are set for density changes (for R, G, B), color-balance changes (for R-G, R-B, G-B). As shown in Table 1, ISO defines common criteria for all colors in one property. On the other hand, Wilhelm defines various criteria for each color according to the importance of each one. With these end points, we can estimate the life of printing materials. For example, the earliest one in all items shall be defined as the life of a printing material.

Table 1. Criteria of each method #: applied, -: not applied

			ISO	Wilhelm	Image Grade N	
Mono-color	Density	R[Cyan]	Δ30%	Δ30%	*	
		G[Magenta]	Δ30%	Δ25%	*	
		B[Yellow]	Δ30%	Δ30%	*	
Gray	Density	R	Δ30%	Δ25%	*	
		G	Δ30%	Δ20%	*	
		B	Δ30%	Δ30%	*	
	Color balance	R-G	Δ15%	+12%,-15%	*	
		R-B	Δ15%	Δ18%	*	N=4
		G-B	Δ15%	Δ18%	*	
Dmin	Density	R	Δ0.10	Δ0.06	-	
		G	Δ0.10	Δ0.06	-	
		B	Δ0.10	Δ0.15	*	
	Color balance	R-G	Δ0.06	Δ0.05	-	
		R-B	Δ0.06	Δ0.10	-	
		G-B	Δ0.06	Δ0.10	-	

Image Grade N

“Image Grade N” is the index that shows total quality integrating monocolor fading, gray fading, and stain.[3] In the prior study, we proposed this method for life estimation of AgX materials. Setting only one criterion, we can estimate the life of a printing material.

Image Grade N is calculated with the process shown in Figure 1. As shown in Eq. (1), “N” is the weighed sum of index “n”s, n_m for monocolor, n_g for gray, and n_s for stain.

$$N = \{n_m(monocolor)\cdot W + n_g(gray)\cdot 1.5\cdot W\} + n_s(stain)\cdot Z \quad (1)$$

where, for n_m(monocolor) and n_g(gray),

$$n = \frac{n_Y + n_M + n_C}{3} - \frac{3\cdot(\Delta n_{YM} + \Delta n_{MC} + \Delta n_{CY})}{10} \quad (2)$$

for n_s(stain),

$$n = -20\cdot D_B + 8 \quad (3)$$

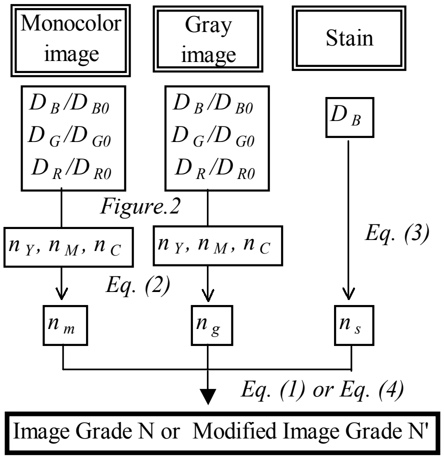

Figure 1. Calculation process of Image Grade N and Modified Image Grade N'

Retentions of density (D_B/D_{B0}, D_G/D_{G0}, D_R/D_{R0}) are converted to ranks, n_Y, n_M, n_C. These are based on the relationship between the ranks of Blue Scale and their retention of density when exposed to light of 10kLangrey (Figure 2a). The index n_m and n_g are calculated from n_Y, n_M, n_C with Eq. (2) which contains a term representing color density fading along with a term representing color balance correction. For stain, n_s is calculated from D_B with Eq. (3). According to the prior research, weighing factor W, Z, and criterion of N for estimating the end point are set as following, W=0.2, Z=0.5, N=4.

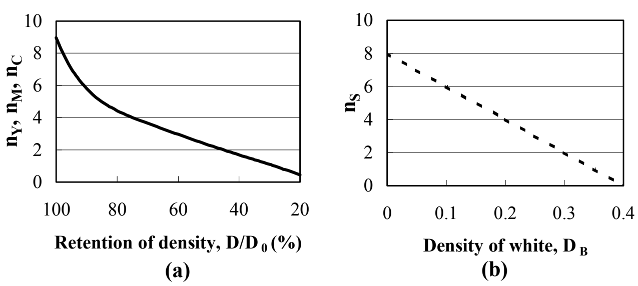

Figure 2. Relationship between index "n" and density, (a) monocolor and gray fading, (b)stain

New method, Modified Image Grade N'

The new method, "Modefied Image Grade N'", assumes an additional point of view, which takes in the degradation balance of color images and stain. It is intended to be effectively applicable to non-AgX printing materials.

The degradation balance of color images and stain in non-AgX printing materials is often much different from that of AgX. As is often the case especially with D2T2 or inkjet printing materials, color images fade greatly but the substrate is still very white. In these cases, Image Grade N doesn't fall so much because it is the simple sum of color image term and stain term. So we arranged the equation style to Eq. (4).

$$N' = \frac{4\cdot\{n_m(monocolor)\cdot W + n_g(gray)\cdot 1.5W\}\cdot\{n_s(stain)\cdot Z\}}{\{n_m(monocolor)\cdot W + n_g(gray)\cdot 1.5W\}+\{n_s(stain)\cdot Z\}} \quad (4)$$

When color image term and stain term are equal, N' is equal to N. On the other hand, when one term becomes much less, N' is strongly affected by one.

Experimental

Samples

11 printing systems consisting of AgX, Photo-Thermographic, Thermal, D2T2, Xerography and Inkjet were selected. Two types of images, physical chart for measuring density and picture image (Figure 3), were printed.

Figure 3. Images for xenon exposure testing

Xenon Light Exposure Testing

Xenon light exposure testing was performed on printing samples. Illumination intensity was set at 85klux and cycle exposure (light 3.8hrs / dark 1.0hrs) was applied. To simulate indirect sunlight coming through a window, UV cut filter (T_{50}=366nm) was set between the light source and samples. Based on typical display conditions, 500lux and 12hrs/1day,[4] this test is accelerated 270 times to simulate normal indoor display conditions.

Subjective Evaluation Testing

Subjective evaluation testing was performed on picture samples after xenon light exposure testing. Six experts for image evaluation judged the end point for each system.

Results and Discussion

Calculation of End Points

End points with four methods were calculated using density of patches before and after exposure testing. Density was measured for cyan, magenta, yellow, gray (initially at D=1.0 level), and white. Here, end points are converted into the corresponding periods in the case of typical display conditions mentioned above.

There are several end points for one material with ISO 10977 and Wilhelm method. They are according to each criterion. Examples of end points are shown in Table 2 for Photo-Thermographic printing material. Based on ISO, the earliest one, the end point of stain color balance (R-B) can be the life of this material. The estimated life is 6 years. In the same way on Wilhelm method, monocolor density (G) is the earliest. The estimated life is 9 years.

Table 2. Examples of calculating end points with ISO 10977 and Wilhelm method; for Photo-Thermographic printing materials

			ISO 10977		Wilhelm	
			Criteria	End point (years)	Criteria	End point (years)
Mono-color	Density	R[Cyan]	Δ30%	10	Δ30%	11
		G[Magenta]	Δ30%	9	Δ25%	9
		B[Yellow]	Δ30%	10	Δ30%	19
Gray	Density	R	Δ30%	16	Δ25%	11
		G	Δ30%	18	Δ20%	14
		B	Δ30%	18	Δ30%	≧20
	Color balance	R-G	Δ15%	≧20	+12%,-15%	≧20
		R-B	Δ15%	18	Δ18%	20
		G-B	Δ15%	-	Δ18%	-
Dmin	Density	R	Δ0.10	-	Δ0.06	-
		G	Δ0.10	-	Δ0.06	-
		B	Δ0.10	-	Δ0.15	-
	Color balance	R-G	Δ0.06	-	Δ0.05	-
		R-B	Δ0.06	6	Δ0.10	-
		G-B	Δ0.06	8	Δ0.10	-
The earliest of all items				*6*		*9*

On the other hand, end point with Image Grade N or Modified Image Grade N' is so simple as shown in Figure 4. There is only one end point for each method. The estimated life is 20 years with N, 18 years with N '.

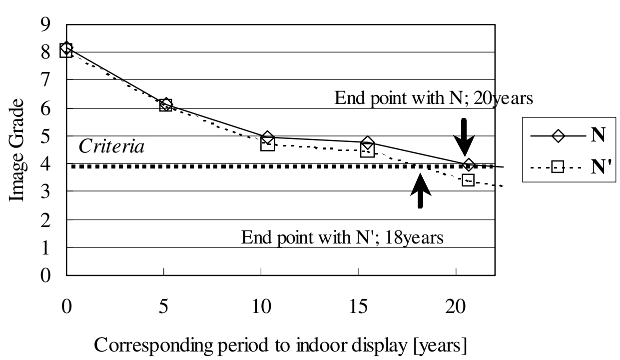

Figure 4. Examples of end points with Image Grade N and Modified Image Grade N'; for Photo-Thermographic printing material

Estimated life of each material with subjective evaluation and calculation is listed in Table 3.

Discussion of the Suitability

Relationship between subjective evaluation and calculation is discussed. Correlations between life estimated using four methods and life using subjective evaluation are examined. RMSE is used to evaluate the suitability. It is calculated with Eq. (5).

$$RMSE = \sqrt{\frac{\sum(\Delta t)^2}{11}} \quad (5)$$

Table 3. Life estimation with subjective evaluation and calculation (years)

	Subjective Eval	ISO	Wilhelm	Image Grade N	Modified Image Grade N'
AgX	≧20	16	17	≧20	≧20
Photo-Thermographic	15 18	6 13	9 10	20 ≧20	18 20
Thermal printing	2 5	2 2	3 4	5 7	4 7
D2T2	13 3	10 2	10 2	≧20 10	17 5
Xerography	≧20	9	17	≧20	≧20
InkJet/Dye	18 3	8 4	7 3	≧20 ≧20	19 7
InkJet/Pigment	≧20	≧20	≧20	≧20	≧20

Life estimated using ISO and Wilhelm methods tend to be shorter than using subjective evaluation. Relationship is shown in Figure 5 and 6. In some cases total impression of images is still at an acceptable level even if any one of the criteria reaches the threshold. It shows the importance to evaluate total quality in life estimation.

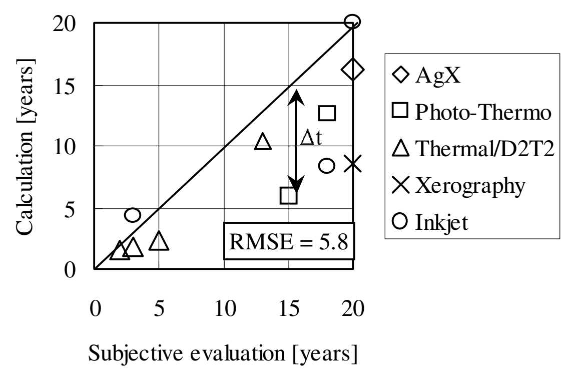

Figure 5. Relationship between subjective evaluation and calculation with ISO 10977

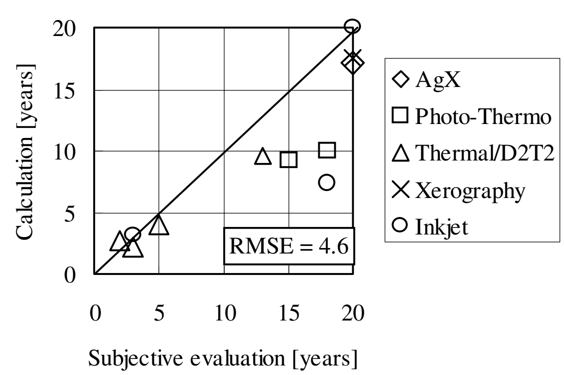

Figure 6. Relationship between subjective evaluation and calculation with Wilhelm method

Life with Image Grade N tends to be longer. As shown in Figure 7, it is remarkable for inkjet and D2T2 materials. In these materials, N doesn't falls so much because substrates remain very white though color images fade greatly.

With the modification of the equation to Modified Image Grade N', relationship of these materials becomes much better as shown in Figure 8. It shows the importance of applying degradation balance of color image and stain. Correlation (RMSE) is the best of four methods.

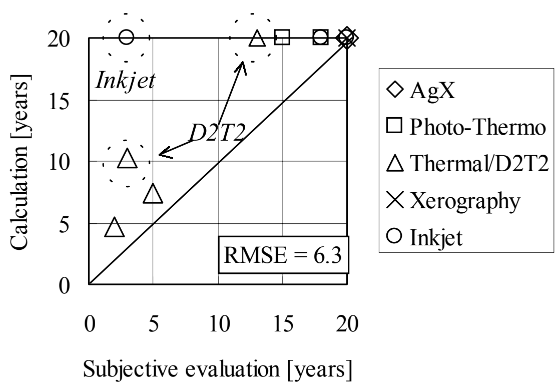

Figure 7. Relationship between subjective evaluation and calculation with Image Grade N

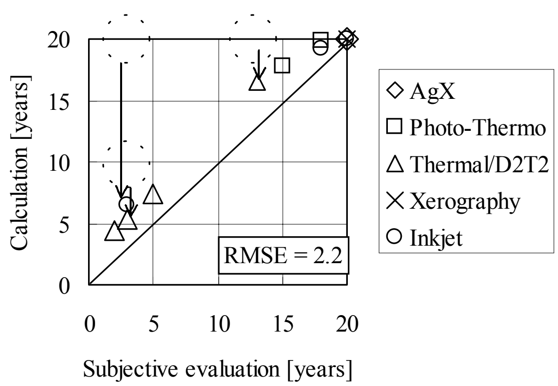

Figure 8. Relationship between subjective evaluation and calculation with Modified Image Grade N'

Conclusion

In estimating the life of digital printing materials, taking account of the total image quality is extremely important. Modified Image Grade N', which reflects this point of view and integrates color and stain degradation with their balance, appropriately estimates the life of printing materials, especially of Non-AgX digital printing materials such as inkjet and D2T2.

References

1. ISO 10977 (1993)
2. Henry Wilhelm, *Proc. IS&T's 12th International Symposium on Photofinishing Technology*, pg. 32. (2002).
3. Yoshio Seoka, Image Preservation Research Group, The Society of Photographic Science and Technology of Japan, *Preservation, display, and restoration of photography*, Musashino Create, pg. 80. (1996).
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Biography

Hiroshi Ishizuka received his master's degree in engineering from Tokyo Institute of Technology in 1989. He has worked in the Ashigara Research Laboratories at Fuji Photo Film Co., Ltd. in Japan. His work has focused on the development and evaluation of imaging materials and systems.