Determining Chromaticness Difference Tolerance of Offset Printing by Simulation

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Keywords: tolerance, offset, chromaticness, midtone spread, simulation

Abstract

Color printing tolerances in ISO 12647-2 have been specified by TVI and midtone spread. ISO TC130 is contemplating to replace midtone spread by chromaticness difference (ΔC_h). In order to find the equivalence between midtone spread and ΔC_h, this research uses a simulation to generate a large database with print jobs that are in conformity to midtone spread requirements as well as print jobs that are not. The results show that the tolerance of 5 midtone spread for a quarter-tone (25C19M19Y) triplet is 1.8 ΔC_h. The tolerance of 5 midtone spread for a midtone (50C40M40Y) triplet or three-quarter (75C66M66Y) triplet is 3.2 ΔC_h. The finding provides insights into the determination of ΔC_h tolerance that aligns with the existing midtone spread tolerance of 5.

Introduction

ISO 12647-2 (2004) specifies solid, TVI, and mid-tone spread as conformance metrics for offset lithographic printing. Solid is assessed colorimetrically. TVI can be computed either densitometrically or colorimetrically (ISO13655). Midtone spread is a measure of grey reproduction and is derived from TVI values of cyan, magenta, and yellow at 50% tonal value (ISO 12647-1). In the revision of ISO 12647-1, ΔC_h, a colorimetric term, is introduced as a new metric for grey reproduction assessment at three pre-determined tonal levels, i.e., quarter-tone (25C19M19Y), midtone (50C40M40Y), and three-quarter (75C66M66Y).

ΔC_h and tone reproduction were used for press calibration (CGATS TR 015). G7 uses a set of pre-determined CMY neutral triplets, color of the printing paper, and color of the CMY overprint solid to define tone reproduction and grey balance aims for these triplets (CGATS TR 015, 2011). The conformity assessment is carried

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out by computing weighted ΔL^* and weighted ΔC_h between color measurement with the aims, and comparing the results to the G7 pass/fail guidelines to determine pass/failure outcome of the job (IDEAlliance, 2012). Instead of using weighted tolerance, Chung and Wang proposed the use of unweighted ΔC_h tolerance to assess G7 pass/fail (PICRM-09, 2011).

Research questions

ISO/DIS 12647-2 specifies grey reproduction tolerance not exceeding 5 midtone spread at 30% and 60% dot area (ISO, 2012). It merely provides an example of ΔC_h tolerances at the three pre-determined tonal levels. To define tolerances for ΔC_h in terms of un-weighted ΔC_h at three tonal levels, this research equates the tolerance between mid-tone spread and ΔC_h by means of a simulated printing database. The research question is, "What is the equivalent ΔC_h tolerance to a midtone spread tolerance of 5?" Since chromaticness difference, ΔC_h, can be assessed at different tonal regions of a grey scale, chromaticness difference at the quarter-tone and at the three quarter-tone region were also tested in this research.

Experimental

It is assumed that grey reproduction depends more on printed CMY tints than printed CMY solids. This research is divided into two parts: (A) simulate printing variation based on TVI changes of CMY tints, and (B) determine ΔC_h that results in optimal agreement with the existing midtone spread tolerance of 5. Figure 1 describes how printing variations are simulated as TVI drifts. A detailed description of each step follows.

A1. Define tonal values. A 10-patch custom target, including solids, 50% tints, paper white, and three CMY near-neutral patches, was designed.

A2. Define printing aims. The Fogra39 dataset was chosen to define printing aims for all printing conditions. Printing aims for non-conforming paper were substrate corrected based on the white point of the printing paper per ISO 13655 (ISO, 2009).

A3. Define actual printing conditions. The relaxed G7 pass/fail requirements are that average $w\Delta L^*$ and average $w\Delta C_h$ are less than 2.0, and max $w\Delta L^*$ and max $w\Delta C_h$ are less than 4.0 (Urbain and Chung, 2012). There are many printing jobs that conform to the G7 pass/fail requirements. In this experiment, four actual printing conditions (Fogra 39, #4071, #4161, and #4208) were selected as the actual printing conditions. G7 conformity assessment of these four printing conditions is shown in Table 1. Grey reproduction characteristics of these four printing conditions are included in the Appendix A.

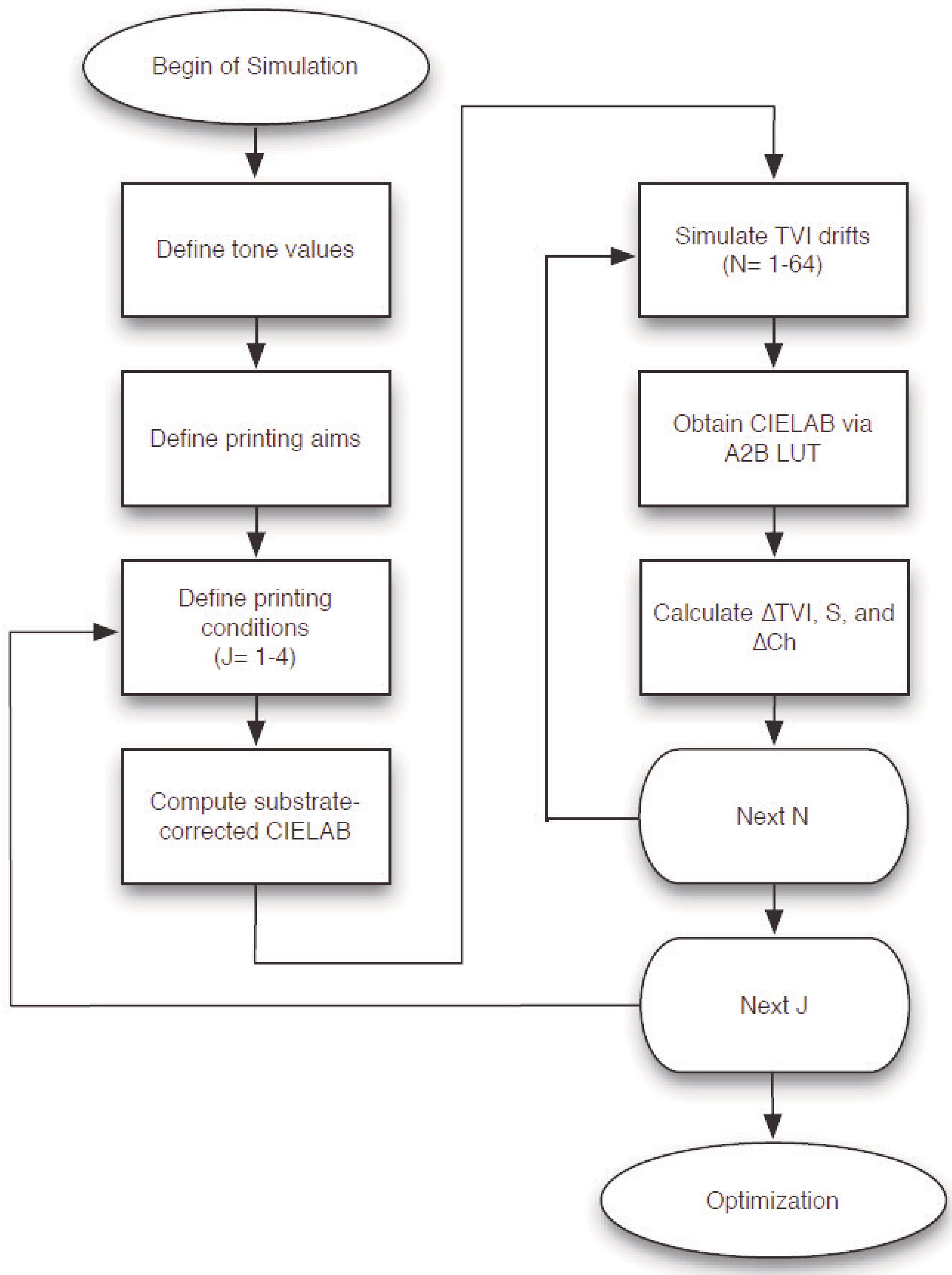

Figure 1. *Simulate printing variation based on TVI changes of CMY tints*

G7 Conformity Assessment		Case 1 (Fogra39)	Case 2 - 4071	Case 3 - 4161	Case 4 - 4208
TR - CMY	Ave wΔL*	0.62	0.32	0.16	0.71
	Max wΔL*	1.52	1.09	0.45	1.58
TR - K	Ave wΔL*	1.03	0.75	1.26	0.67
	Max wΔL*	2.04	1.96	3.74	1.46
GB - CMY	Ave wΔCh	0.44	1.32	0.79	1.25
	Max wΔCh	0.76	3.98	1.66	2.34

Table 1. *G7 conformity assessment of the four actual printing conditions*

A4. Conduct TVI drift simulation. The simulations included both conforming and non-conforming midtone spread conditions. Five levels of deviation from TVI aims (-4, -2, 0, +2, and +4) were explored. Specifically, 64 cases sampled TVI drift with 32 conforming and 32 non-conforming midtone spread conditions.

A5. Calculate substrate-corrected colorimetric aims (SCCA) for the actual printing conditions.

A6. For each actual printing condition, 64 TVI drift simulations were conducted in Photoshop using 'Image > Adjustments > Curves' tool to alter CMY tonal values according to the TVI drifts.

A7. The CIELAB values of modified tonal values were calculated using the A-to-B look-up table of the ICC profile in the ColorThink 3.0 Pro.

A8. Calculate ΔTVI, s (midtone spread), and ΔC_h for the TVI simulation.

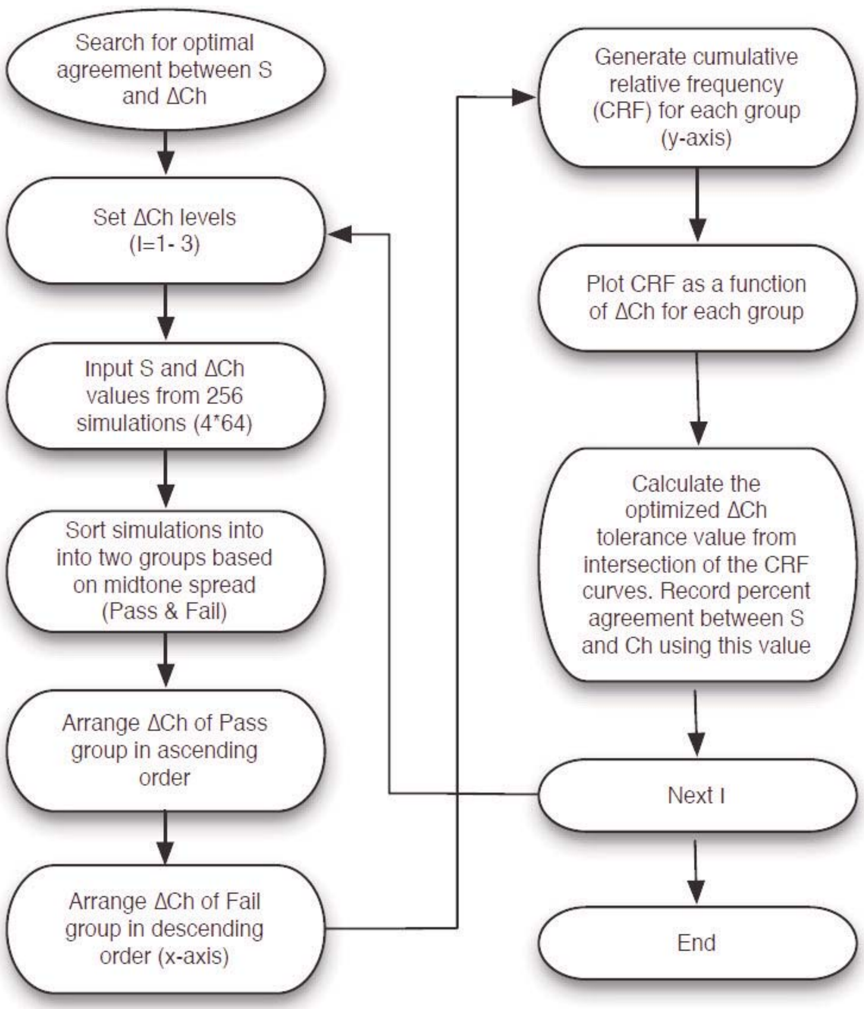

Figure 2. *Optimize ΔC_h and Midtone Spread Agreement Flowchart*

To find the optimal agreement between ΔC_h tolerances and midtone spread tolerances, this research used the methodology described in Billmeyer and Saltzman's Principles of Color Technology (Berns, 2000). Figure 2 describes the procedure for determining the optimal ΔC_h and midtone spread agreement.

B1. Divide all simulations into two parts: conforming and non-conforming per midtone spread of 5.

B2. Sort all the conforming cases from the smallest to the largest ΔC_h. Plot the cumulative relative frequency (CRF) curve vs. ΔC_h values of the conforming part.

B3. Sort all the non-conforming cases from the largest to the smallest ΔC_h. Plot the cumulative relative frequency (CRF) curve vs. ΔC_h values of the non-conforming part in the same graph as Step B2.

B4. The intersection of the two CRF curves represents the optimal agreement between ΔC_h and midtone spread of 5.

Results and Discussion

Optimal ΔC_h at midtone spread of 5

For the midtone (50C40M40Y) triplet, 256 TVI drifts were simulated from four different printing conditions. Figure3 shows that 3.2 ΔC_h and midtone spread of 5 has 88% agreement.

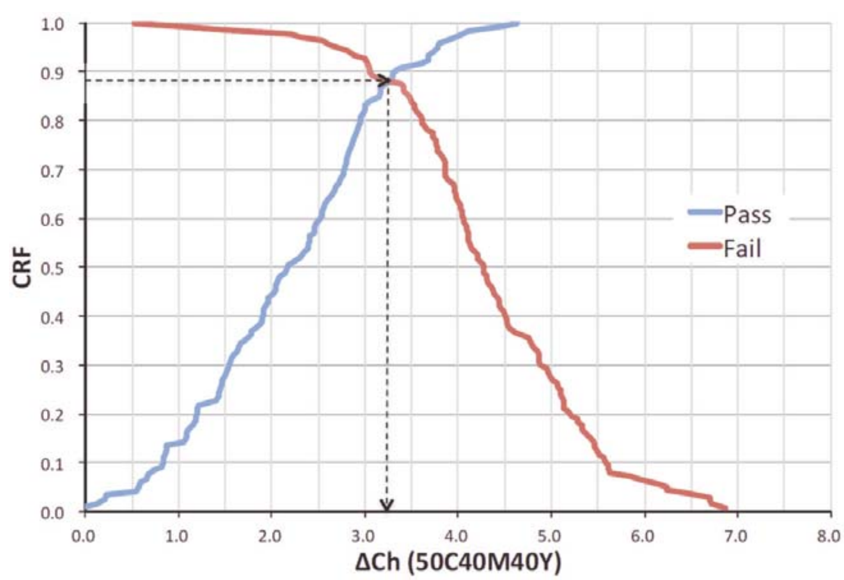

Figure 3. *Equivalency between midtone ΔC_h and midtone spread of 5*

Table 2 summaries the %Agreement between the optimal ΔC_h and midtone spread of 5 in three tonal levels from four different printing conditions. The optimal ΔC_h tolerance exhibits nearly 90% agreement for quarter-tone and midtone triplets, and nearly 80% agreement for the three quarter-tone triplet. The results provide insights into the determination of ΔC_h tolerance that aligns with the existing midtone spread tolerance of 5.

Near-neutral Triplet	MTS (s)	ΔC_h	%Agreement
25C19M19Y	5	1.8	87
50C40M40Y	5	3.2	88
75C66M66Y	5	3.3	77

Table 2. *%Agreement between the optimized ΔC_h and MTS tolerance of 5 of all four cases*

Effect of tonal values and actual printing conditions on ΔC_h

Table 3 summaries the agreement between the ΔC_h and midtone spread of 5 in three tonal levels and for each of the four printing conditions. There are two important observations to make. First, the magnitude of ΔC_h depends on the tonality. Here, ΔC_h is smaller for the quartertone triplet and is larger for midtone and three- quartertone triplet. Second, the %Agreement between ΔC_h and midtone spread of 5 varies in different printing conditions. This points out the importance of having multiple printing conditions to simulate a printing database.

Near-neutral Triplet	#1_Fogra39		#2_4071		#3_4161		#4_4208	
	ΔC_h	%Agree	ΔC_h	%Agree	ΔC_h	%Agree	ΔC_h	%Agree
25C19M19Y	1.7	97	1.8	94	1.8	94	2.1	73
50C40M40Y	3.1	100	3.2	88	3.0	94	3.6	75
75C66M66Y	2.9	91	4.0	72	2.8	94	2.7	75

Table 3. *Percent agreement between the optimized ΔCh and MTS tolerance of 5 case by case*

Disagreement between ΔC_h and midtone spread

While Figure 4 shows the optimal ΔC_h that corresponds to the midtone spread of 5, it does not explain possible causes for disagreement between midtone ΔC_h and midtone spread. Figure 4 correlates between midtone ΔC_h and midtone spread for all 256 samples. The red triangles, located at upper right, represent failed samples because their midtone spread values are greater than 5. The green solids, located at lower right, represent passed samples because their midtone spread values are less than or equal to 5. The red circled triangles represent failed samples with ΔC_h less than or equal to 3.2. The green circled solids represent passed samples with ΔC_h greater than 3.2. This gives us a basis to explore the disagreement between midtone ΔC_h and midtone spread.

Sample 95 is a simulation of Case 4208 with a 4% increase in magenta TVI and 2% increase in yellow TVI (Table 4). This results in a large midtone spread of 5.69. But, ΔC_h of the midtone triplet is as small as 0.52.

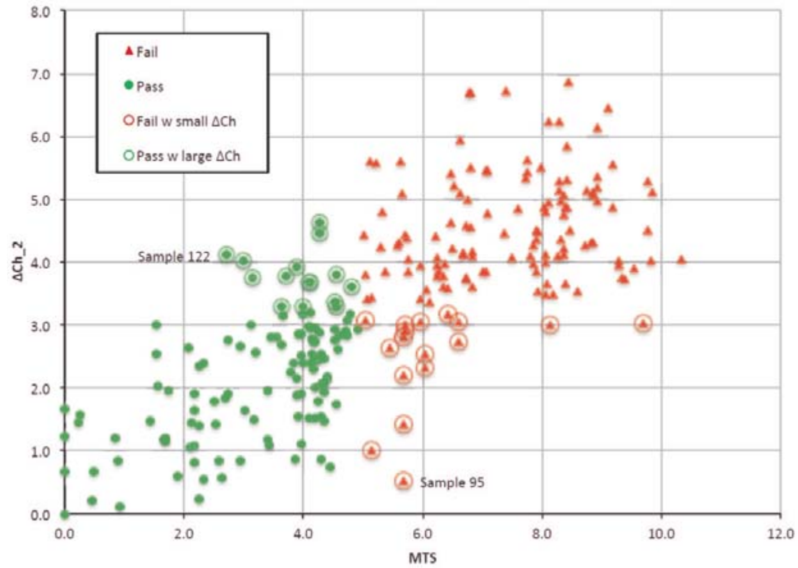

Figure 4. *Pass and fail samples in terms of MTS and ΔC_h*

Sample_95	Sample Name	CMYK_C	CMYK_M	CMYK_Y	CMYK_K	L*	a*	b*	50% TVI	s	ΔCh
A0	100% Cyan	100	0	0	0	56.11	-36.84	-47.20			
A1	50% Cyan	49.8	0	0	0	74.22	-18.17	-24.05	15.34		
A2	100% Magenta	0	100	0	0	49.61	72.41	-2.48			
A3	50% Magenta	0	53.7	0	0	67.89	37.76	-3.85	19.31	5.69	
A4	100% Yellow	0	0	100	0	87.67	-4.51	94.34			
A5	50% Yellow	0	0	51.8	0	90.28	-4.33	45.39	15.67		
A6	Paper white	0	0	0	0	92.74	-0.09	1.04			
A7	25% CMY	24.7	20.8	20	0	74.75	0.84	1.98			1.53
A8	50% CMY	49.8	43.5	42	0	55.92	0.91	0.96			0.52
A9	75% CMY	74.9	69.4	67.5	0	37.91	3.37	2.40			3.31

Table 4. *Sample 95 simulation*

Sample 122 is also a simulation of Case 4208 with a 4% increase in cyan TVI (Table 5). This results in a small midtone spread of 2.71. But, ΔC_h of the midtone triplet is as large as 4.11.

Sample_122	Sample Name	CMYK_C	CMYK_M	CMYK_Y	CMYK_K	L*	a*	b*	50% TVI	s	ΔCh
A0	100% Cyan	100	0	0	0	56.11	-36.84	-47.20			
A1	50% Cyan	53.3	0	0	0	73.07	-19.07	-25.43	18.05		
A2	100% Magenta	0	100	0	0	49.61	72.41	-2.48			
A3	50% Magenta	0	49.8	0	0	70.51	33.28	-3.71	13.62	2.71	
A4	100% Yellow	0	0	100	0	87.67	-4.51	94.34			
A5	50% Yellow	0	0	49.8	0	90.37	-4.22	42.77	12.93		
A6	Paper white	0	0	0	0	92.74	-0.09	1.04			
A7	25% CMY	27.1	18.8	18.8	0	75.05	-1.46	0.49			2.02
A8	50% CMY	53.3	40	40	0	56.21	-2.89	-1.63			4.11
A9	75% CMY	77.3	65.9	65.9	0	38.90	-0.29	1.95			1.00

Table 5. *Sample 122 simulation*

Both Sample 95 and Sample 122 are from Case 4208. By connecting the substrate-corrected color aims (SCCA) to the starting point of Case 4208, the length of the line is the magnitude of the ΔCh for the starting point of Case 4208 (Figure 5). This means that the 50C40M40Y triplet resulted in greenish grey in relation to the aim.

Sample 95 represents a 4% increase in magenta TVI and a 2% increase in yellow TVI. It yielded a larger midtone spread (5.69), but resulted in the small ΔC_h (0.52) or a short line between SCCA and Sample 95. On the other hand, Sample 122 represents a 4% increase in cyan TVI. It resulted in a small midtone spread (2.71), but a large ΔC_h (4.11) or a long dashed line between SCCA and Sample 122, as shown in Figure 6.

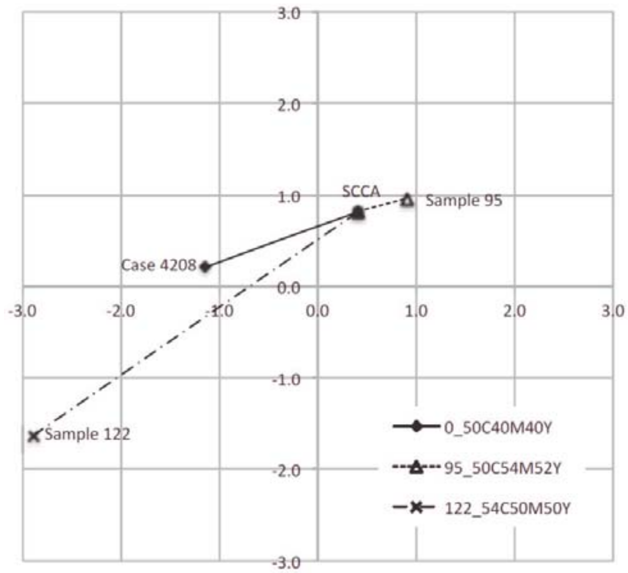

Figure 5. *a* and b* plot of 50% triplets of Case 4208*

Conclusions

Using simulation of TVI variations, based on multiple actual printing conditions, to create a printing database to determine ΔC_h that aligns with midtone spread is a novel approach in the research. We recommend the use of three triplets and their associated ΔC_h as the equivalent midtone spread of 5 in the revision of ISO 12647-2 (Table 6). We also recommend a follow-up study that involves a large real printing database.

Near-neutral Triplet	MTS (s)	ΔC_h
25C19M19Y	5	1.8
50C40M40Y	5	3.2
75C66M66Y	5	

Table 6. *Recommended grey reproduction (ΔC_h) tolerances*

When CMY triplets are pre-determined, their CIELAB or ΔC_h values depend on the reference characterization dataset (including substrate corrected color aims) and the actual printing conditions (measurement). When midtone spread and ΔC_h are highly correlated, both parameters are indicative of grey reproduction. When midtone spread and ΔC_h are not correlated, the use of pre-determined triplets and ΔC_h are better indication of grey reproduction than midtone spread.

Acknowledgments

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Appendix A.

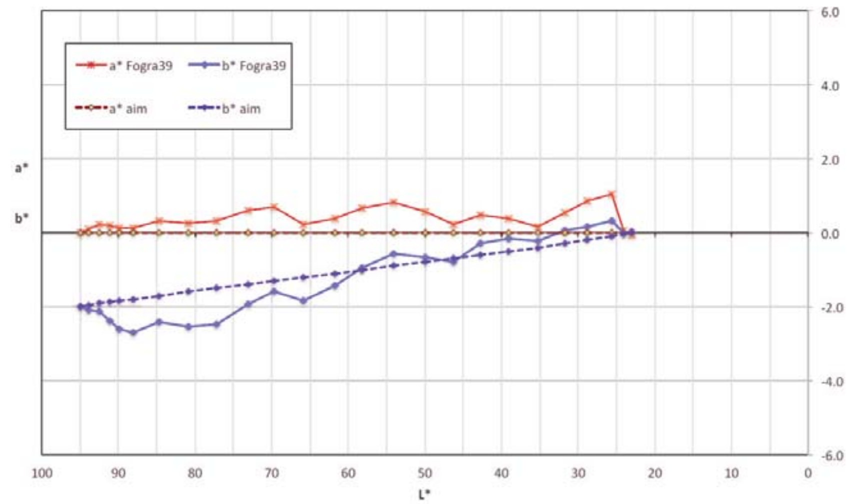
Grey reproduction characteristics of the four printing conditions

From previous studies, grey reproduction of pre-determined CMY triplets vary the most in the shadow region (Chung and Wang, 2011). If the entire database is based from only one printing condition, we will not be able to simulate grey reproduction behaviors of the real world printing. Thus, Fogra39 and the other three printing conditions, selected from the G7 database, are used in this study.

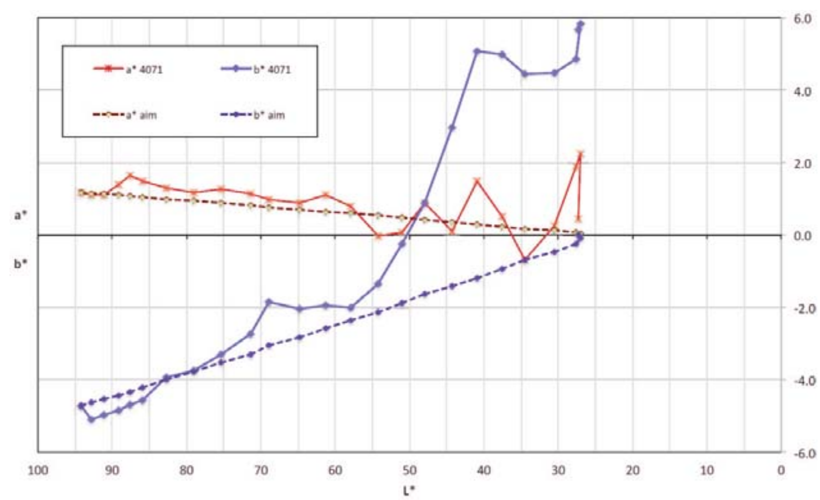
Note that the two straight converging lines, based on paper color and the color of the TACmax are theoretical in nature. None of the pre-determined CMY triplets follow these lines exactly.

With the addition of these cases, the simulation accurately modeled the large deviations frequently reported in the shadow tones. Thus, the simulation now provides a solid foundation for developing ΔC_h tolerances aligned with current midtone spread tolerances.

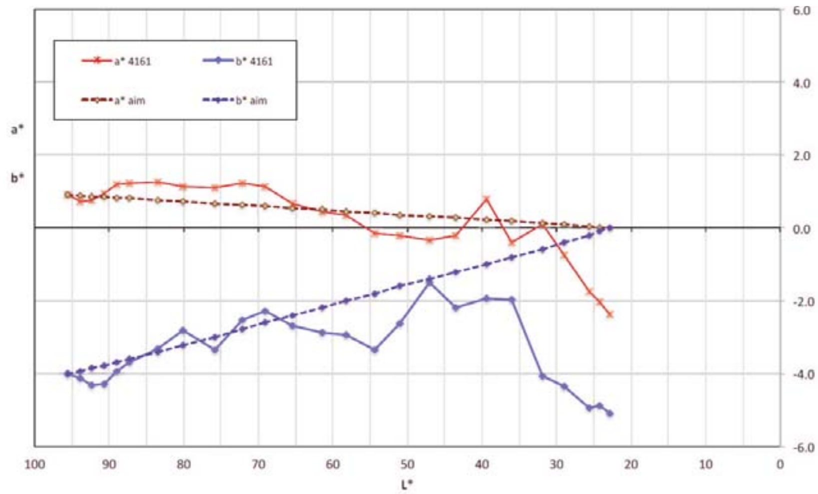
Case 1_Fogra39



Case 2_4071



Case 3_4161



Case 4_4208