Specification of Gonioapparent Color and Appearance

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Introduction

Instrumentation for multi-angle color measurement has been available for the last 30 years. ASTM E2194 [1] and E2539 [2] specify angles to be used in measuring Gonioapparent colors. ASTM D 2244 [3] provides several widely used color difference and color tolerance equations. These are based on visual assessments of equal color difference around select color centers. While these equations provide color differences, D2244 also states “For product specification, the purchaser and the seller shall agree upon the permissible color tolerance between specimen and reference ---”. Gonioapparent colors are generally flake-containing, so they also exhibit spatial appearance characteristics, referred to as sparkle (as observed under directional, collimated light such as sunlight) and graininess (visual texture as observed under diffuse light such as an overcast sky). The only commercial instrument currently available to measure these attributes is the BYK-mac. Sparkle (S_a, S_i, S_g) is measured at viewing angles of 15º, 45º and 75º. Graininess (G) is measured under diffuse illumination. BYK uses these measurements to calculate sparkle differences between standard and batch specimens (dS) at each of the three angles and ΔG. This paper summarizes methodology and status of a Detroit Colour Council study of visual assessments to determine the magnitude of differences in S and G judged as acceptable over the gamut of real automotive colors.

Experimental Process

Typical automotive colors were chosen for this study. For each of the colors, pigment ratios were varied to provide samples varying in sparkle and graininess. Pairs of these samples were identified such that they increased in sparkle or graininess difference while keeping the color difference as small as possible. These pairs were shown in random order to observers, all experienced in judging commercial acceptability of automotive color and appearance differences. They were asked: “Ignoring any color differences, would you accept this sparkle difference between two adjacent car parts on your car?” This process was repeated under each of the sparkle angles and under diffuse light for graininess.

All visual assessments were done in a byko-spectra effect viewing booth. This allows sparkle difference assessments at viewing angles of 15º, 45º and 75º. The 45º viewing angle was used to assess graininess differences, with a diffuser over the light source in order to minimize sparkle. The viewing port was partially masked on either side to ensure lateral centering of observer positioning over the separation line between the two panels being assessed.

Observer-to-observer differences in visual assessments result in a sigmoidal response when frequency of acceptability as judged by a large number of observers is plotted against the parameter difference. Logit analysis is very effective in analyzing sigmoidal responses. The logit function (Equation 1), when plotted against the parameter difference, effectively linearizes this response. The parameter difference at 50% frequency is a good indicator of acceptability.

$$Logit = log\left[\frac{f}{(1-f)}\right], \qquad (1)$$

where f = frequency of acceptance

One would expect each observer's response to be a step function as an increasing parameter difference crosses from "acceptable" to "unacceptable". However, subjectivity in visual assessments results in noise in each observer's judgments as parameter differences increase. The initial observer data were smoothed using the algorithm in reference [4].

Results and Discussion

Typical results are shown in Fig. 1 for a bright yellow metallic automotive paint. The table on the left shows the CIE94 color difference, observer smoothed acceptance frequency, logit values, and the 15º dS for each sample pair.

Std ID	Bch ID	DE94	frequency	Logit	dS
4	5	0.17	0.13	-0.81	0.31
2	11	0.25	0.17	-0.70	0.41
9	10	0.26	0.20	-0.60	0.53
8	9	0.28	0.07	-1.15	0.63
7	9	0.40	0.07	-1.15	0.69
5	6	0.17	0.13	-0.81	0.74
4	6	0.33	0.13	-0.81	0.83
5	7	0.35	0.07	-1.15	0.94
3	4	0.18	0.27	-0.44	0.99
2	3	0.22	0.40	-0.18	1.10
8	10	0.54	0.60	0.18	1.15
3	11	0.46	0.60	0.18	1.23
6	10	0.83	0.67	0.30	1.47
5	9	0.74	0.70	0.37	1.65

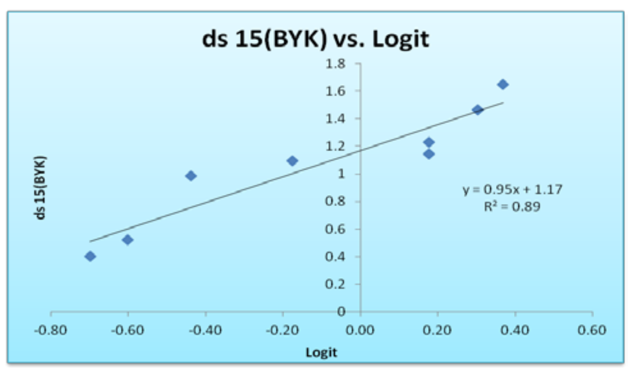

Figure 1. 15º Observations and Logit plot for a bright yellow metallic paint

Observations with frequencies below 0.15 (shown in red) were ignored because they fall beyond the linearity of the logit function. The remaining data points are shown in the plot on the right. A least squares fit shows very good linearity (R^2 = 0.89). The intercept of 1.17, corresponds to a frequency of 50% acceptability. An alternate process, Binary Logistic Regression (Figure 2) allows use of all the data points and determines 50% acceptability at dS = 1.26.

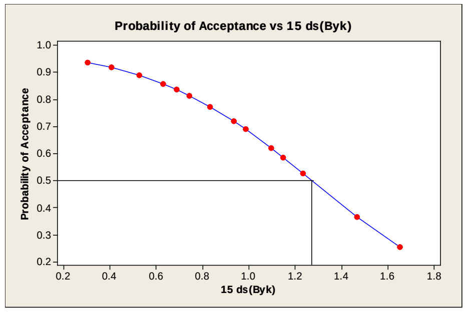

Figure 2. Binary Logistic Regression determination of 50% of acceptability

Path forward

Several additional colors are being studied using this methodology. They will be reported on in the presentation. For completeness, the study will include assessments by suppliers to the automotive industry, automobile manufacturers, as well as other countries represented on the committee. Final data analysis will look for any differences between these groups. Multiple colors will also allow analysis of dependence of sparkle or graininess acceptability on factors such as angle of view, lightness or other properties of the color being assessed.

References

1. ASTM D2194, Standard Practice for Multiangle Color Measurement of Metallic Flake Pigmented Materials, ASTM International, Conshohocken, PA 19428-2959.
2. ASTM D2539, Standard Practice for Multiangle Color Measurement of Interference Pigments, ASTM International, Conshohocken, PA 19428-2959.
3. ASTM D2244, Standard Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates, ASTM International, Conshohocken, PA 19428-2959.
4. Berns RS, Alman H, Reniff L, Snyder GD, Balonon-Rosen MR. Visual Determination of Suprathreshold Color-Difference Tolerances Using Probit Analysis. Color Res Appl 1991; 16:297-316

Author Biography

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