Specification of Gonioapparent Color & Appearance

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Presentation Outline

• Multiangle Color Measurement Summary
• DCC Committee Purpose
• Project Background
• Experimental Procedures
• Data Analysis
• Results
• Graininess Study
• Pathforward
• Acknowledgement
ASTM Geometry for Multiangle Color Measurement

E2194 recommendation for metallic colors. Solid lines are the preferred angles for critical measurements.

E2539 Specified geometries for measuring the color range due to Interference. The E2194 geometries are used for measuring color due to scattering or orientation.

<table>
<thead>
<tr>
<th>Illumination Angle</th>
<th>Detection Angle</th>
<th>Aspecular Angle</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>45°</td>
<td>-60°</td>
<td>-15°</td>
<td>45°:-60° (as -15°)(ca 52.5)</td>
</tr>
<tr>
<td>45°</td>
<td>-30°</td>
<td>+15°</td>
<td>45°:-30° (as +15°)(ca 37.5)</td>
</tr>
<tr>
<td>15°</td>
<td>-30°</td>
<td>-15°</td>
<td>45°:-30° (as -15°)(ca 22.5)</td>
</tr>
<tr>
<td>15°</td>
<td>0°</td>
<td>+15°</td>
<td>15°: 0° (as +15°)(ca 7.5)</td>
</tr>
</tbody>
</table>

Note—This table gives the minimum geometries for the quality control application. For other applications, additional geometries; such as 65°:-50° (as15°), may be desirable or needed.
Committee Purpose: Upgrade SAEJ1545 with the goal of standardizing automotive industry practices for establishing color and flake appearance measurement and methodology for setting meaningful tolerances.

Membership
Chairman: Jeff Alspach, Axalta, Mt. Clemens, MI
Car manufacturers: Audi, Ford, GM (need others)
Coatings Suppliers: AkzoNobel, Axalta, BASF, PPG
Instrument Manufacturers: BYK-Gardner, X-Rite, GTI
Includes members from ASTM, CIE, DIN

March 2013 Sub-committee Meeting Attendees
Project Background

• The BYK-mac multi-angle spectrophotometer is applied in measuring the color and flake appearance differences of automotive paints.

BYK-mac

• Previous experiments on metallic blue color and black color
• Process: estimate sparkle difference tolerances for several colors by visual assessment and using “Logit Analysis”.
BYK-mac Geometry

Courtesy of BYK-Gardner, GmbH
Basic Equations and Terms

• Used $\Delta E_{94}$ color differences with the gonioparentent $S_L$ Lightness correction

• Sparkle difference $dS$ as provided by the BYK-mac

• Sparkle definition (ASTM E12.01): **Sparkle**, n- The aspect of the appearance of a material that seems to emit or reveal tiny bright points of light that are strikingly brighter than their immediate surround and are made more apparent when a minimum of one of the contributors (observer, specimen, light source) is moved.
Experimental Procedures

- The panels are observed in the BYKO-Spectra Effect lightbooth.
- The viewing window on the lightbooth is shortened from 20 in. width to 5 in. width (helps focus on the center of the panels)
Experimental Procedures

• 30 observers were asked to make visual assessments of sparkle difference acceptability. All of the observers had experience in judging automotive color and appearance acceptability.

• Panel pairs were randomly presented.

• Panels supporting board set at 45 degree, allowing viewing perpendicular to the panels with the sparkle light at 15, 45 or 75 degrees. The light intensity is adjusted to 7 (1 to 10 scale).

• Tapes at four corners help focus on the center
Experimental Procedures

Following is an example of the process used in selecting sample pairs for visual assessments:

11 panels combined to a total of 55 pairs of panels with known dE94 and dS measured by BYK-mac at the appropriate angle

- dE94 < 1
  - 39 pairs of panels left
- dS < 1.3 (assumes 1.3 close to 100% rejection)
  - 23 pairs of panels left
- choose pairs evenly spaced for 0.30 < ds < 1.30, dE94 < 0.85
  - 12 pairs left

(Add dS pairs close to expected high and low rejection)
Experimental Procedures

- Observers were asked:
  “Ignoring any color differences, would you accept this sparkle difference between two adjacent car parts on your car?”
  --Accept, “YES”
  --Reject, “NO”

- Assessment Template

<table>
<thead>
<tr>
<th>Bright Yellow</th>
<th>Observations of Sparkle Difference at 15 Degree</th>
<th>Date: 7/25/2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question: Ignoring any color differences, would you accept this sparkle difference between two adjacent car parts on your car?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Std ID</td>
<td>Bch ID</td>
<td>Std ID</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Observer:</td>
<td>Observer:</td>
<td>Observer:</td>
</tr>
</tbody>
</table>
Observer Data Smoothing

This process compensates for subjective variation in each observer’s assessment

Almost everyone accepts low dS pairs
Everyone rejects high dS pairs

Logit linearizes a cumulative normal distribution allowing determination of a tolerance, dS at a reasonable acceptance rate (e.g. 50%)

Logit function linearizes region of interest
Logit = log \( \frac{f}{1-f} \)

Typical frequency of rejection versus metric difference

Logit analysis

\[
y = -3.1100 + 4.0714x \quad R^2 = 0.998
\]
Typical Visual Assessment Results

<table>
<thead>
<tr>
<th>Std ID</th>
<th>Bch ID</th>
<th>dE94 15 ds</th>
<th>15 dS</th>
<th>Rej Freq</th>
<th>logit</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>6</td>
<td>0.30</td>
<td>0.92</td>
<td>0.107</td>
<td>-0.92</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>0.37</td>
<td>0.97</td>
<td>0.107</td>
<td>-0.92</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>0.33</td>
<td>1.27</td>
<td>0.143</td>
<td>-0.78</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>0.72</td>
<td>1.48</td>
<td>0.286</td>
<td>-0.40</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>0.23</td>
<td>1.57</td>
<td>0.536</td>
<td>0.06</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td>0.59</td>
<td>1.60</td>
<td>0.571</td>
<td>0.12</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>0.47</td>
<td>1.75</td>
<td>0.714</td>
<td>0.40</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>0.26</td>
<td>1.84</td>
<td>0.464</td>
<td>-0.06</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>0.80</td>
<td>2.08</td>
<td>0.607</td>
<td>0.19</td>
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<tr>
<td>2</td>
<td>5</td>
<td>0.51</td>
<td>2.41</td>
<td>0.786</td>
<td>0.56</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>0.37</td>
<td>2.43</td>
<td>0.893</td>
<td>0.92</td>
</tr>
</tbody>
</table>

A 50% frequency of rejection (Logit = 0) is the recommended tolerance

Logit = 1.1264dS - 1.9506

$R^2 = 0.8695$

Tolerance = 1.73
Binary Logistic Regression (w / Logit link function)

- Variable: dS 15 Blue
- Tolerance: 1.73
# Summary of Sparkle Studies to-date

<table>
<thead>
<tr>
<th></th>
<th>ds15</th>
<th>ds45</th>
<th>ds75</th>
<th>dG</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cyber Gray</strong></td>
<td>?</td>
<td>✔</td>
<td>✔</td>
<td>NO</td>
</tr>
<tr>
<td><strong>Black</strong></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔*</td>
</tr>
<tr>
<td><strong>Blue</strong></td>
<td>✔</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td><strong>Brt Yellow</strong></td>
<td>✔</td>
<td>?</td>
<td>NO</td>
<td>NO</td>
</tr>
</tbody>
</table>

* Graininess results discussed later
## Results

<table>
<thead>
<tr>
<th></th>
<th>Avg L*</th>
<th>Avg C*</th>
<th>Tolerance</th>
<th>Logit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cyber Gray</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>18.27</td>
<td>1.91</td>
<td>0.79</td>
<td>Logit = 2.29dS - 1.86</td>
</tr>
<tr>
<td>75</td>
<td>7.22</td>
<td>1.54</td>
<td>1.08</td>
<td>Logit = 2.63dS - 2.85</td>
</tr>
<tr>
<td><strong>Black</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>18.61</td>
<td>2.87</td>
<td>1.71</td>
<td>Logit = 1.71dS - 2.92</td>
</tr>
<tr>
<td>45</td>
<td>4.79</td>
<td>0.5</td>
<td>1.50</td>
<td>Logit = 1.38dS - 2.07</td>
</tr>
<tr>
<td>75</td>
<td>2.67</td>
<td>0.53</td>
<td>0.77</td>
<td>Logit = 1.25dS - 0.96</td>
</tr>
<tr>
<td><strong>Blue</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>54.42</td>
<td>58.43</td>
<td>1.73</td>
<td>Logit = 1.12dS - 1.95</td>
</tr>
<tr>
<td><strong>Bright Yellow</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>77.79</td>
<td>59.75</td>
<td>1.18</td>
<td>Logit = 0.93dS - 1.10</td>
</tr>
</tbody>
</table>
Results:

Comparison of 15 degree sparkle differences for Blue, Bright Yellow, and Black

- Blue: Logit = 0.93dS - 1.11
  Tolerance = 1.18
- Bright Yellow: Logit = 1.13dS - 1.95
  Tolerance = 1.73
- Black: Logit = 1.71dS - 2.92
  Tolerance = 1.71
Equivalent results using binary linear regression
Graininess Study

- Graininess: Visual texture observed under cloudy day with diffused illumination

Images Courtesy of BYK-Gardner, GmbH
Graininess Study

Preliminary limited study on black

- BYKO-Spectra Effect lightbooth: color evaluation source at 45 degrees. Light diffusion was enhanced with two layers of white tissue over light source.

- Six observers as a start using the same visual assessment process and analysis method, total 11 panels and 14 pairs

Note: 6 observers are not sufficient. More data points and a better estimate of graininess acceptability will be available as observers are added.
Overall Progress on Specification of Gonioapparent Color & Appearance

**Color**
- ✓ Definitions in ASTM E284
- ✓ Measurement of metallic – ASTM E2194
- ✓ Measurement of pearls – ASTM E2539
- ✓ Update SAE J5145

**Spatial Appearance**
- ✓ Definitions in ASTM E284
- ? ASTM standard on measurement of spatial appearance
- ? Revision of SAE J1545
Pathforward

• Additional visual assessments for additional sparkle angles and other metallic colors to estimate the sparkle and graininess difference tolerances.

• Include observers from OEM’s and other coatings suppliers.

• Explore generalized tolerances, e.g., possible relationship to color, lightness, hue, chroma, contrast, etc.
Acknowledgements

• BYK-Gardner for their support and providing the BYKO-Spectra Effect lightbooth for the visual assessments

• Members of the DCC Committee

• DCC for their sponsorship

• Our colleagues in Axalta Coating Systems for their inputs and participation in visual assessments

• In advance to suppliers of future color sets and participants in on-going experiments
Thank You!
Any Questions?
ASTM E12.01 Definitions

**sparkle-intensity**, *n*—the contrast between the appearance highlights on the particles of a gonioapparent pigment and their immediate surround.

**sparkle-area**, *n*—the area segment of the illuminated portion a sample surface with light-spots that are strikingly brighter than their immediate surround.

**sparkle**, *n*—The aspect of the appearance of a material that seems to emit or reveal tiny bright points of light that are strikingly brighter than their immediate surround and are made more apparent when a minimum of one of the contributors (observer, specimen, light source) is moved. Discussion—Sparkle is perceived under intense directional illumination only

**graininess**, *n*—the perceived contrast of the light/dark irregular pattern exhibited by gonioapparent coatings when viewed under diffuse illumination, scale typically < 100 micrometers. Discussion—Also referred to as *diffuse coarseness*. 
**ASTM E12.01 Definitions**

**texture, n**—the visible structure depending on the size and organization of small constituent parts of a material; typically, the surface structure of a woven fabric, or subsurface structure of a gonioapparent material. (C460)

**glint, n**—see preferred term **sparkle**.

**diffuse-coarseness, n**—see preferred term **graininess**.

**Spatial appearance, n**—those attributes of appearance that have a spatial component including texture, graininess, sparkle, etc.

Discussion—For fabrics the spatial dimension is usually <10 mm, for painted materials the spatial dimension is usually, < 1mm.