Agenda

- Measurement and Specification of Gonioapparent Color and Appearance
  - Objective
  - Background
    - Color Measurement
      - Solid and Gonioapparent
    - Appearance Measurement
      - Solid and Gonioapparent
    - Standards (ASTM, DIN, CIE, SAE)
      - Work done
      - Work ongoing
  - Challenges
  - Path Forward
    - Proposed future work

What we know

What we don’t know
Objective…

For Measurement and Specification of Gonioapparent Color and Appearance…

The goal is to minimize difficulty and ambiguity in rendering color and appearance decisions through an improved understanding of the relationship of measured and viewed differences. That improvement will allow the use of objective methods to consistently determine said differences. This coupled with a tolerance methodology can drive meaningful and achievable color and appearance specifications. This can make the decision process easier and help lead to an improved color and appearance harmonization across all materials.

Gonioapparent Materials

Gonioapparent, adj - pertaining to change in appearance with change in illumination angle or viewing angle. (ASTM E 284-09a). Preferred term vs. “effect” to differentiate from other effects such as fluorescence.

Gonioapparent materials / colors

- Usually contain flat platelike particles
- Show changes in lightness, hue, and/or chroma with changes in illumination and/or viewing angle

Classic examples:

- Aluminum flake
- Mica pearl flake

ASTM terminology standard E284 has a list of ~80 terms relating to gonioappearance
Background…

Key Factors Affecting Gonioapparent Color And Appearance Measurement…

- Material in Standard and batch
- Hiding
- Travel
- Metamerism
- Color Space
- Instrument Type (Geometry and calibration Method)
- Application
- Appearance (Gloss, Haze, DOI, Grain, Sparkle, Graininess)
- Correlation to Visual

Background…

History of gonioapparent color measurement …

1935 First metallic automotive paints
1964 First batch of metallic paint instrumentally shaded
1986 SAE J1545 Published (Only dealt with solid colors)
1987 First presentations of 3-angle measurement of metallic finishes (ISCC Williamsburg Conf.)
  • D. H. Alman “Directional Measurement of Metallic Flake Finishes”
  • W. H. Venable “A Model for Interpreting Three-Angle Measurements of Flake Finishes”
  • L. E. Steenhoek “Goniophotometry as an Appearance Research Tool”
1988 First use of portable 3-angle instrument on automotive assembly line
1989 ASTM Task-Force E12.03.02 (now E12.12) on “Metallic and Pearlescent Color” chartered
2001 First DIN standard (DIN 6175-2) on tolerances for goniochromatic automotive paints
2003 First ASTM standard (E-2194) “Multiangle Color Measurement of Metal Flake Pigmented Materials”
2005 SAE J1545 Revised (extended for gonioapparent materials)
2008 ASTM standard (E-2539) “Multiangle Color Measurement of Interference Pigments”
**Background…**

**History of gonioapparent appearance measurement …**

Traditional Appearance measurements…
- Gloss/Haze/DOI/luster/Texture

Contemporary Appearance measurements…
- Sparkle/Glint/Graininess

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**Color Difference Equations**

\[
\Delta E = \left[ \frac{\Delta L^*}{K_L S_L^*} \right]^2 + \left[ \frac{\Delta C^*}{K_C S_C^*} \right]^2 + \left[ \frac{\Delta H^*}{K_H S_H^*} \right]^2 \right]^{0.5}
\]

Resulted from databases of visual observations of solid color differences

DIN 6175-2 was based on observations of gonioapparent colors

*CIE94 has been extended to gonioapparent colors

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Background...

Color Difference Equations ...

CMC
- Developed based on single observer assessments of color differences between card windings
- Widely used improvement over CIE76, even beyond the textile industry
- Inaccurate for gonioapparent with reflectance factors greater than 100%

CIE94
- Well planned experiment and data analysis process
- Carefully chosen color centers broadly covering color space (Glossy non-textured coatings)
- 50 observers
- Extended to metallics covering a lightness range from $L^* = 6.00$ to 140.33

Din 6175-2
- Only a limited number of special effect color shades were used in defining the model parameters.
- All observations done by a single observer.
- Separate standard for solid colors(6175) provides discontinuity.
- DIN committee is currently considering an appropriate replacement.

Appearance Background...

**Must match Color and Appearance**

- **Surface texture differences**
  - Diffuse measurement
    - Match
  - Visual assessment
    - Mis-match
  Must match gloss, haze, DOI

- **Gonioapparent color**
  - **Flake**: size, orientation, surface smoothness
  - Overall: flop, sparkle, visual texture

Sparkle, Graininess images courtesy of BYK-Gardner
Pigment Types and Interaction with Light

Absorption Pigments
- specific color due to selective absorption and scattering of light

Metallic Pigments
- metallic gloss due to mirror-like reflection of light

Interference Pigments
- specific color, luster and color flop due to interference of light

Effect Color Appearance

Effect colors have unique appearances not seen in solid colors:

- color travel
- lightness texture
- sparkle (50x).
Effect Color Travel

Effect colors contain metallic or pearlescent flake pigments, also called effect pigments.

These large, flat pigments tend to orient parallel to the coating surface.

Oriented effect pigments in the color coat produce the light to dark color travel appearance.

Background of Industry Standards…

For Measurement and Specification of Gonioapparent Color and Appearance…

- Standards for Instrumental Color Measurement

- Standards for Instrumental Appearance Measurement

- Standards for Both or Unification?
Background of Industry Standards…

Why use an Industry Standard…

- Common Assessment Method
- Common Terminology for Communicating
- Effort spent on Continual improvement vs. Creating Different Standards

International Standards for Measurement
Designation for Gonioapparent Materials
(ASTM designation)

ASTM E 2539-08

- Recommended Geometry
  - 45:-30(as15)  45:0(as45)  45:65(as110)
International Standards for Measurement of Metal Flake Pigmented Materials

ASTM E 2194-03

- Recommended Geometry
  - 45:-30(as15), 45:0(as45), 45:65(as110)
- Alternates
  - 45:-25(as20), 45:-20(as25) instead of 45:-30(as15) (allows for less sensitivity to application variation)
  - As low as 45:25(as70) instead of 45:65(as110)
  Warning that these may occasionally not agree with visual

DIN 6175-2

- Recommended Geometry
  - 45:-20(as25), 45:0(as45), 45:65(as110) or 45:30(as75)

SAE J1545

For Measurement and Specification of Gonioapparent Color and Appearance...

- INSTRUMENTAL COLOR DIFFERENCE MEASUREMENT FOR EXTERIOR FINISHES, TEXTILES, AND COLORED TRIM
  - Objective method vs. subjective
  - Delivers good correlation to visual with proper
    - R&R
    - Controlled surroundings
    - Sample handling
    - Standards handling
    - Use the right instrument for the material
    - How to set proper tolerances
  - Instrument agrees better with a group of observers
  - Reference to E 2194 Standard for Measurement of Gonioapparent Material
ASTM Standard for Measurement of Interference Pigments

ASTM E 2539

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

No standard for colors containing interference pigments because 3-angles for measurement of metallic color differences of current automotive colors was found sufficient.

Appearance Standards...

For Measurement and Specification of Gonioapparent Color and Appearance...

- E284-06b Standard Terminology of Appearance
- E1767-04 Practice for Specifying the Geometries of Observation and Measurement to Characterize the Appearance of Materials
Visual Standards…

For Measurement and Specification of Gonioapparent Color and Appearance…

- ASTM Subcommittee E12.11 Visual Methods
- WK4911 Standard Practice for Estimating the Colorimetric Effects of Light-on-Object Colors (In Progress)

Summary…

Color and Appearance…
- Summarize pros and cons of current standards for color and appearance of solid and gonioapparent materials

<table>
<thead>
<tr>
<th>Color</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrumental</td>
<td>Standards with angles specified</td>
<td>Correlation to visual for future more exotic colors might need done.</td>
</tr>
<tr>
<td>Visual Appraisal</td>
<td>Standards exist.</td>
<td>Need proper equipment, enough observers, and proper data set.</td>
</tr>
<tr>
<td>Data Sets (color centers)</td>
<td>Standards exist.</td>
<td>Extremely Limited (Need real auto colors)</td>
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<tr>
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<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrumental</td>
<td>Standards exist.</td>
<td>Need revised for gonioapparent materials.</td>
</tr>
<tr>
<td>Difference Equations</td>
<td>Traditional (gloss/haze/etc.)</td>
<td>Need robust gonioapparent dataset to evaluate which is best and how best to set weightings.</td>
</tr>
<tr>
<td>Visual Appraisal</td>
<td>Standards exist.</td>
<td>Need proper equipment, enough observers, and proper data set.</td>
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Challenges…

For Measurement and Specification of Gonioapparent Color and Appearance…

- Need to create a valid data set(s) (Can 1 set be used for both properties?)
- Need to evaluate these data both instrumentally and visually
- Need to create and/or revise a standard(s)
- Need resources to do all the above

If a goal is to integrate both properties into 1 standard, it must handle both solid and gonioapparent products.

Path forward…

For Measurement and Specification of Gonioapparent Color and Appearance…

- If there is enough interest and support
  - Put a committee together under DCC to create and analyze the data sets
  - Analyze the data and make proposals to standards organizations
Acknowledgement…

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