Objective Evaluation of the Visual Assessment of Yacht Finishes

Joint research project OFIN sponsored by BMWi

Matthias Schneider
Manh-Hung Tran
Philipp Knee
Ulrich Hoffmann

Coating Technology Division
Fraunhofer IPA, Stuttgart

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Objectives

- Evaluation of **appearance** on large surfaces
- Survey of available methods
- Effect of **ultra-long wavelengths** $\lambda > 10$ cm on appearance
- Comparison of *wave-scan* measurements on yachts with automobile benchmark
- Results of **joint research project** OFIN
- **Objective evaluation methods** for appearance alongside visual evaluation

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Evaluation of Appearance on Large Surfaces

Present

- **Visual evaluation** of leveling, gloss and local defects (e.g., runs or dirt inclusions) to create a subjective overall picture of the optical quality
- Appearance measurement by *wave-scan* device
- **Gloss** and **haze** measurement of top coat by *reflectometer* (DIN EN ISO 2813)
- Substrate **roughness** by *profilometry* (DIN EN ISO 4287)

New developments

- **OFIN research project**: New evaluation methods for large surfaces
- Bring existing testing techniques in line with **visual perception** of large surfaces
- Analysis and further development of existing and potentially usable methods
Evaluation of Measuring Techniques on Yacht

Assessment by measuring device on ship (e.g., paint film leveling by *wave-scan*)

Assessment by measuring device on ship (e.g., coating defects by digital microscopy)
Build-up of Coats and Coating Processes

Coating methods:
1 Airless
2 Pressure tank
3 Airmix

- Top Coat 2x (1)
- Base Coat 2x (1)
- Fine Putty EP
- Putty EP
- Antifouling 2x (1)
- Barrier Coat 2x (1)
- Sealer (1)
- Holding Primer (1)

Steel
Build-up of Coats – Profilometry

Surface structures of intermediate layers in complete build-up of coats

Strong increase in profilometer We-values (long-wavelength structures 10-30 mm) due to sanding of fine putty and primer

Complete build-up of coats

- Protective Primer
- Fine putty
- Base coat 1
- Base coat 2
- Top coat 1 blue
- Top coat 2 blue
- Top coat 1 green
- Top coat 2 green

Graph showing changes in surface roughness $R_q$ [$\mu$m] with build-up stages Wa [0.1-0.3 mm], Wb [0.3-1 mm], Wc [1-3 mm], Wd [3-10 mm], and We [10-30 mm].
Methods of Evaluation – Influencing Factors and Conditions

<table>
<thead>
<tr>
<th>Surface geometry</th>
<th>Viewing distance</th>
<th>Light intensity</th>
<th>Position of surface</th>
<th>Viewing direction</th>
<th>Frequency of viewing</th>
<th>Yacht area</th>
<th>Lighting</th>
<th>Kind of light</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• plane</td>
<td>• bright (&gt;1000 lx)</td>
<td>• horizontal</td>
<td>• perpendicular (0°)</td>
<td>• permanently</td>
<td>• owner</td>
<td>• directed</td>
<td>• natural daylight</td>
</tr>
<tr>
<td></td>
<td>• convex</td>
<td>• moderate</td>
<td>• vertical</td>
<td>• inclined (ca. 45°)</td>
<td>• regularly</td>
<td>• guests</td>
<td>• diffuse</td>
<td>• artificial light</td>
</tr>
<tr>
<td></td>
<td>• concave</td>
<td>• low</td>
<td>• diagonally diverging</td>
<td>• very inclined (ca. 80°)</td>
<td>• rarely</td>
<td>• crew</td>
<td>• shadows</td>
<td>• both</td>
</tr>
<tr>
<td>Frequency of viewing</td>
<td>• &lt; 1 m</td>
<td>•</td>
<td></td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 1 - 3 m</td>
<td>•</td>
<td></td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 3 - 10 m</td>
<td>•</td>
<td></td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• &gt; 10 m</td>
<td>•</td>
<td></td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Methods of Evaluation – Sectioning of Yacht Surface

Coated surface areas with different influencing factors and conditions
# Measuring Techniques

## Color / Effect

- Color measuring device / Gonio-photometer
- Color-Guide, portable color measuring device (spectrometer)

## Gloss / Haze

- Reflectometer / Haze meter
- TRI-Gloss, Micro-Haze

## Long/Shortwave Distinctness of Image (DOI)

- Appearance measuring device
- Wave-scan DOI

## Surface Structure

- Profilometer (laser-optical or mechanical)
- Hommel Tester T1000

## Coating Defects

- Mobile digital microscope with 3D profile measurement

<table>
<thead>
<tr>
<th>Color / Effect</th>
<th>Gloss / Haze</th>
<th>Long/Shortwave Distinctness of Image (DOI)</th>
<th>Surface Structure</th>
<th>Coating Defects</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.jpg" alt="Image" /></td>
<td><img src="image2.jpg" alt="Image" /></td>
<td><img src="image3.jpg" alt="Image" /></td>
<td><img src="image4.jpg" alt="Image" /></td>
<td><img src="image5.jpg" alt="Image" /></td>
</tr>
<tr>
<td>✔️ o.k.</td>
<td>✔️ o.k.</td>
<td>✔️ (not for ultra-long-wavelength structures)</td>
<td>lab only</td>
<td>high effort in applying on yacht</td>
</tr>
</tbody>
</table>
Measurements on Yacht by wave-scan

Yacht metallic / average DOI: 77
Comparison automobile dark DOI\(^1\): 93

\(^1\) F. Fensterseifer: Benchmark Study – Upper and Medium Size Automobiles.
### Questioning of Test Persons

<table>
<thead>
<tr>
<th>Distance</th>
<th>Overall impression</th>
<th>DOI</th>
<th>Fine structures (SW)</th>
<th>Coarse structures (LW)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Daylight</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 m</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>3 m</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td><strong>Artificial light</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 m</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>3 m</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Grade 1 = very good / Grade 5 = poor

- Measured value = visual impression
- Measured value ≠ visual impression

Panel #30

LW-SW/DOI values

<table>
<thead>
<tr>
<th></th>
<th>LW</th>
<th>SW</th>
<th>DOI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>29</td>
<td>36</td>
<td>87</td>
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</tbody>
</table>

Grade 1 = very good / Grade 5 = poor
## Ermittlung der Zone

<table>
<thead>
<tr>
<th>Optionen</th>
<th>≤ 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Betrachtungsabstand [m]</td>
<td></td>
</tr>
<tr>
<td>Betrachtungshäufigkeit</td>
<td>ständig</td>
</tr>
<tr>
<td>Betrachtungsrichtung</td>
<td>senkrecht (0°)</td>
</tr>
<tr>
<td>Beleuchtung</td>
<td>gerichtet</td>
</tr>
<tr>
<td>Lichtart</td>
<td>natürliches Licht</td>
</tr>
<tr>
<td>Lichtintensität</td>
<td>hell (&gt; 1000lx)</td>
</tr>
<tr>
<td>Flächenlage</td>
<td>horizontal</td>
</tr>
<tr>
<td>Flächengestriche</td>
<td>plan</td>
</tr>
<tr>
<td>Yachtbereich</td>
<td>Eigner</td>
</tr>
</tbody>
</table>

(Priorität der Zonen: "1" hoch - "5" niedrig)

## Bewertung-Appearance

<table>
<thead>
<tr>
<th>Optionen</th>
<th>Messwert</th>
<th>Strafpunkte</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farbdifferenz [Δ E*]</td>
<td>bunt</td>
<td>0.0</td>
</tr>
<tr>
<td>Glanzdifferenz [60°]</td>
<td></td>
<td>0.0</td>
</tr>
<tr>
<td>Wb-Kennwert</td>
<td></td>
<td>0.0</td>
</tr>
<tr>
<td>Wd-Kennwert</td>
<td></td>
<td>0.0</td>
</tr>
<tr>
<td>Strukturbalance B</td>
<td></td>
<td>0.0</td>
</tr>
<tr>
<td>DOI-Kennwert</td>
<td>dunkel</td>
<td>84.0</td>
</tr>
</tbody>
</table>

Σ Strafpunkte Appearance 84.0

## Einschürze

<table>
<thead>
<tr>
<th>Kontrast: Lack/Partikel</th>
<th>gering</th>
<th>hoch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partikelverteilung</td>
<td>lokal</td>
<td>lokal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Partikelgröße [mm]</th>
<th>Anzahl</th>
<th>Strafpunkte</th>
<th>Anzahl</th>
<th>Strafpunkte</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Σ Strafpunkte Einschürze 0.0

Gesamtstrafpunkte 84.0

**Qualitätsindex Appearance** 94

Beurteilung NICHT bestanden
Optimization of Process Technology

Optimization potentials:
workplace design and systems engineering

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Optimization of Process Technology

Optimization potentials:
atomization process, e.g., paint film structure for horizontal coating (wave-scan)
Optimization of Process Technology

Optimization potentials: sanding process

Workplace equipment

Long-necked sander (250 mm)

Disk sanding machine (400 mm)
Optimization of Process Technology

Optimization potentials: sanding process (wave-scan values)
Detection of Ultra-longwave Structures by Defectometry

Paint film leveling and waviness

Reflected stripe pattern (panel ca. $1 \times 1 \text{ m}^2$)
Defectometry – Measuring Results

Waviness values for $\lambda > 30$ mm $W_f$, $W_g$ and $W_h$ for four different test panels
Appearance Assessment on Large Surfaces – Other Areas of Application

Examples: Coatings on airplanes, railway vehicles, buses, etc.

Coating on railway vehicle
Summary and Outlook

- Requirements for new measuring methods on large surfaces
- Analysis of existing methods
- **Visual evaluation** by selected test persons
- Correlation analysis between visual evaluation and measured data
- Testing of image processing for appearance evaluation (e.g., mirroring of stripe patterns)
- Measurement already **during build-up of coats** (»show coat«)
- Analogy with audit systems in automotive industry